Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 261 MARCH, 1956 No. 3

FRANKLIN AND THE TWENTIETH CENTURY*

BY

I. BERNARD COHEN[1]

A half century ago the philosopher Charles Sanders Peirce explored canons of greatness, wondering whether there might be some rule or set of rules to tell who were the century's great men. Definitions of greatness, he felt, were only like rules of grammar; these do not "render an expression bad English, but only generalize the fact that good writers do not use it." Hence, according to Peirce, "in order to establish a definition of greatness, it would be necessary to begin by ascertaining what men were and what men were not great, and that having been done the rule might as well by dispensed with." Peirce's own "opinion" of the matter seems a strange issue from a mind steeped in logical analysis, a mind which invented the term "pragmatism." It is the romantic "opinion," which more of us hold than are apt to be willing to admit the fact in public, and so we may understand why Peirce stated that his "opinion . . . has not been lightly formed nor without long years of experimentation." But he did fear that "some intellectual men" would consider only as "foolishness" the view "that the way to judge of whether a man was great or not is to put aside all analysis, to contemplate attentively his life and works, and then to look into one's heart and estimate the impression one finds to have been made. This is the way in which one would decide whether a mountain were sublime or not. The great man is the impressive personality, and the question whether he is great is a question of impression."

We do not hold Franklin to be a great man, and gather to celebrate the 250th anniversary of his birth, because of objective standards that

* Address delivered at the 250th Anniversary Dinner, held in conjunction with the Annual Meeting of The Franklin Institute, Wednesday, January 18, 1956

[1] Chairman of the Committee on Higher Degrees in the History of Science & Learning, Harvard University, Cambridge, Mass.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

set him apart from other men of his day—as that he belonged to more scientific societies, had more honorary degrees, signed more treaties, made more discoveries, or wrote more laws—but rather because our sentiments find in his person a symbolic image of our values and our aspirations. The impression of the heart, evoked by Peirce, is not purely subjective in the sense of being one man's reaction; it is bound in time to the qualities of the age—our age even more than Franklin's. At the founding of this republic Franklin was considered to be the "father" of his country, a title we now associate with Washington on whom it was only later conferred. The father image was a natural one to the men of the 1780's because they had only to look about them to see that he was their patriarch. Franklin had been the oldest member of the Second Continental Congress in 1776 and he was again the oldest delegate to the Constitutional Convention in 1787. He had been active in his country's affairs when most of the other great men had been only boys. In 1754, almost 50, he had advocated a united America, drafting the Albany Plan of Union, when Washington was barely out of his teens, Jefferson was eleven, John Adams nine, and Madison but three years old. Even in the 1760's his political opponents had begun to call him "pappy," his wife's favorite nickname. If he was a contemporary of Jefferson, Washington, Hamilton and Madison, he had also been a contemporary of Increase and Cotton Mather and he had been born less than a century after the death of Shakespeare.

In the nineteenth century Franklin no longer was thought of in terms of this image. The "founding fathers" generally included only the men who were active in the early federal period. Franklin ceased to be conceived an architect of our liberties and a daring inventor of new scientific concepts, but became the mentor of material success—the original poor boy who made good. He was considered the teacher of the "Way to Wealth," how to gain material success here and now—the smug, self-righteous and self-made man whose life set a pattern that others might do likewise. His autobiography became a moral tale other than he had intended because the editors removed his confessions of youthful imprudences. Those who published his writings cleansed him of coarse and indelicate phrases and suppressed certain pieces which they considered too "broad" for our delicate national sensibilities. Had the good man returned to earth he would scarcely have recognized his own image and would surely have made the same kind of joke that was evoked on his seeing a portrait made in France in which he had come to look like a Frenchman.

The nineteenth century knew Franklin not only as the author of a guide to success in this world, "The Way to Wealth," but as the inventor of practical devices like the lightning rod, the rocking chair, the Franklin stove, and bifocal glasses. His name immediately evoked

Poor Richard's statement, that a penny saved is a penny earned, words which are inscribed on the walls of savings banks throughout the land. The worth of this precept in the middle of the twentieth century, in an age of plenty and inflation, may be questionable. The value of the penny, in any event, is so small that it would take an extraordinary number of them to make a worth-while savings account. Even the famous one-cent stamp bearing Franklin's likeness is now only a philatelist's curiosity and Franklin now adorns a tuppence card. If we do save pennies, it is probably only to have a supply on hand to feed the parking meters. Curiously enough, the phrase used by Poor Richard was not Franklin's, but an adaptation of William Penn's "A penny saved is a penny got."

For some reason, the nineteenth-century moralists forgot that Franklin's material success came not only from frugality, thrift, and hard work, but derived in even greater measure from heroic initiative. Poor Richard said other things that may attract us today more than the squibb about the pennies. "A house without woman and firelight," he said, "is like a body without soul or sprite." "Where there's marriage without love there will be love without marriage." "Fish and visitors stink in three days." "There are no ugly loves nor handsome prisons." He also said, "There are more old drunkards than old doctors." In the almanac for 1739 Franklin warned: "Be not thou disturbed, O grave and sober reader, if among the many various sentences in my book thou findest me trifling now and then, and talking idly. In all the dishes I have hitherto cooked for thee, there is solid meat enough for thy money. There are scraps from the table of wisdom that will, if well digested, yield strong nourishment to thy mind. But squeamish stomachs cannot eat without pickles; which, 'tis true, are good for nothing else, but they provoke an appetite." Shall we thus comprehend Poor Richard's advice: "Let thy maidservant be faithful, strong, and homely"? Or "Keep your eyes wide open before marriage, half shut afterwards." He also said: "An egg today is better than a hen tomorrow." Two of my favorites are: "A plowman on his legs is higher than a gentleman on his knees"; "Genius without education is like silver in the mine."

As a student of Franklin I have always been struck most by his humane qualities. Never a mealy-mouthed moralizer, he was quite aware that assent given to precepts did not mean they would be adopted in actual conduct. In "The Way to Wealth," he observed that after the people had heard Father Abraham recite the best precepts of Poor Richard, "they approved the doctrine, and immediately practised the contrary, just as if it had been a common sermon." Franklin, plainly, never suffered from the evil of taking himself too seriously. He loved people and he loved conversation and he never lost his sense of humor, even about his own doings and his sayings. He wrote about

himself once, in the *Pennsylvania Gazette*, as "a certain printer," it being "not customary to give names on these occasions," who had been walking "in clean clothes over some barrels of tar . . .," when "the head of one of them unluckily gave way. . . . 'Twas observed he sprang out again briskly, verifying the common saying, as nimble as a bee in a tarbarrel. You must know there are several sorts of bees: 'tis true he was no honey bee, nor yet a bumble bee; but a boobee he may be allowed to be, namely B.F."

Even at serious moments, such as his famous address at the close of the Constitutional Convention, his expressions of high purpose were made palatable by the spice of humor; he could not help telling the delegates a story about a "certain French lady, who, in a dispute with her sister, said: 'But I meet with nobody but myself that is always in the right.'" It is said that the writing of the Declaration of Independence could not be entrusted to Franklin for fear that a pun would be concealed in it. "You know every thing makes me recollect some story," he wrote his daughter and he related an anecdote against pride. A certain gentleman had "built a very fine house, and thereby much impaired his fortune." He took great pride in showing his house to all his acquaintances, one of whom, having seen it, was bothered by a motto carved over the door, "ŌIA VANITAS" it seemed to read. "What," says the friend, "is the meaning of this ŌIA? It is a word I don't understand." The gentleman replied: "I had a mind to have the motto cut on a piece of smooth marble, but there was not room for it between the ornaments, to be put in characters large enough to be read. I therefore made use of a contraction antiently very common in Latin manuscripts, by which the *m*'s and *n*'s in words are omitted, and the omission noted by a little dash above, which you may see there; so that the word is *omnia*, OMNIA VANITAS." "O," replied the friend, "I now comprehend the meaning of your motto; it relates to your edifice; and signifies that, if you have abridged your *omnia*, you have nevertheless left your VANITAS legible at full length."

Writing "Information to those who would remove to America," Benjamin Franklin expressed the aspirations of his age that a country where liberty flourishes and where the laws are just provides opportunity for all men according to their capacities, their initiative and industry, and integrity. In America, he said, any man with a useful art is welcome "and if he exercises it, and behaves well, he will be respected by all that know him; but a mere man of quality, who, on that account, wants to live upon the public, by some office or salary, will be despised and disregarded. The husbandman is in honor . . ., and even the mechanic. . . ." Americans, said Franklin, "are pleased with the observations of a negro, and frequently mention it, that *Bocarrora* (meaning the white men) *make de black man workee, make de horse workee, make de ox workee, make ebery ting workee; only de hog.*

He, de hog, no workee; he eat, he drink, he walk about, he go to sleep when he please, he libb like a gentleman."

The Franklin I have been describing was a warm-hearted gay man who liked people more than he liked things. He preached a way to wealth, but he did not practice avarice—and in his own life and in the counsels he gave to others he was aware of the dangers of too much money and too many things. Wealth was a means to an end and Poor Richard warned that "Avarice and Happiness never saw each other," that "Wealth is not his that has it, but his that enjoys it." Characteristically, when he had accumulated enough wealth to live in modest comfort, he set out to enjoy it by retiring from business so that he could devote himself to research in pure science, to analyzing the mysteries of electrical attraction and repulsion, searching out the secrets of the operation of the condenser or Leyden jar, and studying atmospheric electricity. Because Franklin loved people more than he loved things, he exerted himself in bettering the lives of his fellowmen. His organization of hospitals, schools, fire companies, libraries, and his civic improvements are all instances of his concern for the welfare of his fellow-man. Active in the promotion of religious toleration, he signed his name in support of a synagogue in Philadelphia, aided in the appointment of the first Roman Catholic Bishop in the United States, and conceived of a free house of worship where even a Mahometan might preach.

If, in the nineteenth century, men could be complacent about the battles for freedom of action, thought, and expression, we in the mid-twentieth century see these issues in jeopardy as Franklin did. The impression of the heart, to which Peirce referred in his consideration of the meaning of greatness, finds nourishment in Franklin's straightforward defense of freedom and his continuous activities in behalf of our liberty. If Franklin has any meaning as a symbol for us in the year that marks the 250th anniversary of his birth, if we may find in his writings and his actions any inspiration to strengthen us as we face the problems ahead of us, then the one Franklinian aspect that most commands our attention is that blend of the highest idealism with the empirical temper that marked his life. Franklin's ideals of respect for human dignity and service to man are a part of the age in which he lived and, in some measure, were exemplified in both the Calvinistic Boston of his youth and the Quaker Philadelphia of his young manhood. The environment does not wholly account for any man and in Franklin's case we can see how his personality developed both by accepting and warring against certain features in his background. Clearly, and we have his own testimony in this regard, he was influenced in his career of service to man by his early reading of Cotton Mather's "Essays to do good." But his principles of liberty

were formed by his abhorrence of the rigid theocratic domination of the Mathers and their circle and he never forgot his brother's imprisonment for having dared to assume that the press was free. Each individual reacts differently to his environment and so the development of the personality is still obscure, however illuminated by the genius of Sigmund Freud; we fall back on such poetic phrases as inspiration, well-springs of the heart, or mysteries of the human spirit.

Franklin's empirical temperament is easier to comprehend; after all, every master craftsman is an empiricist, struggling with the brute facts of experience at first hand—and so is the successful businessman. Franklin's "Autobiography" was intended to show, as he said, that he owed the "happiness of my past life" to God's "kind providence, which led me to the means I used and gave them success." But the reader cannot help observing that one of the singular features of Franklin's life as he recounted it is the willingness with which he was able to accept the lessons of experience and to profit from them. Thus he recounted his "faults" and the "sinister accidents" of his life, calling them also his "errata," and he told how he corrected each erratum to the best of his ability. In his reading during the 1740's, this empirical turn of mind led him to study the master-works of experimental science: Newton's *Opticks*, Hales' *Statical essays*, Desaguliers's *Experimental philosophy*, Boerhaave's *Chemistry*, and s'Gravesande's *Newtonian philosophy*. By self-education in the best textbooks of his day, Franklin prepared himself for his later role of experimental scientist. A myth has grown up that when Franklin heard about the new subject of electricity, he had no training in science and that merely by some untrained natural instinct he rapidly became one of the leading scientists of his age, called the "Newton" of electricity because his theory of electrical action and his experiments promised to bring order to that subject as the *Principia* had done for the mechanics of heavens and earth a generation earlier. This myth collapses without further ado when we see the quality of the scientific books Franklin was studying in the decade before he began his electrical experiments. And, at once, when we take cognizance of Franklin's scientific training, his career in science becomes meaningful in its true dimensions.

If I seem to be stressing this point unduly, the reason is that there is a parallel of misunderstanding between Franklin's scientific career and the rest of his life. When we say that Franklin was an experimental scientist we do not mean only that he sought to understand the secrets of nature's operations by direct experience in the laboratory, as opposed to the method of analysis which attempts to comprehend vast ranges of experience within the structure of mathematical equations. The distinction between these two major approaches to science does not lie primarily in the fact that one is based more directly on fruitful experiment, while the other is abstract and theoretical, but

rather that they are two different roads to inventing concepts and building theories to explain, correlate, and order the phenomena observed in the world about us and in the laboratory. The experimental scientist, just like the mathematical scientist, sets as his highest goal the understanding of nature. All observations and all experimental facts are not of equal interest, those that are most significant having the special quality of illuminating an important area of knowledge and suggesting new theories, providing ground for the invalidation of older theories, or opening up new areas in which theories are needed.

Franklin's friend, Joseph Priestley, a distinguished historian of scientific ideas and a man of incisive views about the philosophy of science, wrote in his history of electricity that every important experiment is conceived to test or explore some hypothesis. Two of Franklin's major scientific experiments well illustrate this point. He had conceived a theory of electrical action in which electrification is supposed to occur by the transfer of a subtle elastic fluid. When two bodies are rubbed together, according to this theory, one body gains electric fluid (and so, said Franklin, is charged "plus" or "positive"), while the other body loses electric fluid (and so, in Franklin's language, becomes charged "negative" or "minus"). Now an immediate consequence of this basic hypothesis is that electrifications always occur in such a fashion that the charge produced in one body must be exactly equal to that produced in some other body or bodies, although of the opposite sign, so that in general charges always appear in equal magnitudes of positive and negative electrification. Franklin's contemporaries considered that one of the most important applications of this hypothesis was in the experiments he performed which showed the basic principles of the Leyden jar, or condenser, or capacitor. This jar, made of glass, had two conductors in contact with the glass: an outer coating of metal foil, the inside filled with water or shot. Franklin showed that when one of these conductors is charged by contact, the other one (grounded) becomes charged by a process which we call today "electrostatic induction" or "influence." Franklin devised experiments to prove that the charges obtained by the two conductors on either side of the glass were always of the opposite sign but of equal magnitude. Thus, in a sense, what Franklin showed was that there was no more "electricity" in a charged jar than in an uncharged jar, because one of the two conductors had gained as much electric fluid as the other had lost. We call this principle today the principle of conservation of charge, and it is one of the corner stones of our whole system of physical thought. One of the most famous experiments ever performed by Franklin was to test the electrification of clouds. Here, again, Franklin had adopted an hypothesis—that the lightning discharge is similar to the kind of electric discharges

which he was able to produce in the laboratory. The famous experiments performed in 1752 were designed to verify this hypothesis.

The reason for stressing this aspect of Franklin's scientific career is that it illustrates the thesis that the experimental scientist does not, so to speak, "try everything," that his method is not an uninformed search by "trial and error." He performs particular experiments and makes certain observations which are related to basic principles which he has conceived on the basis of studying other experiments and observations.

J. J. Thomson, one of the founders of the physics of the twentieth century, wrote, "From the point of view of the physicist, a theory of matter is a policy rather than a creed; its object is to connect or coordinate apparently diverse phenomena, and above all to suggest, stimulate and direct experiment." This description applies not only to Franklin's scientific work, but it also illuminates his political life and social thought. The student of political and social thought is sometimes disturbed, when studying Franklin, by the fact that there is not associated with his name a particular doctrine, a formal treatise, some set of rules, or the Franklinian theory of this or that. The name of Washington suggests at once the first president's warning to his countrymen to beware of foreign entanglements. Monroe's name is enshrined forever in his doctrine about Europe and the new world. Franklin stands only for such beliefs as the rights of man, human dignity, respect for liberty, tolerance, and a concern for the rights and needs of others.

As the scientist goes step by step, from one experiment to another, from concept to concept, and from better theory to better theory, so Franklin embodied his ideals in particular actions that would help to make a better world for his countrymen to live in. He was concerned with the daily issues of experience, guided by his general principles. In these terms, we may understand one aspect of the secret of Franklin's success in the world of men.

Franklin was a confirmed abolitionist, and some of the last things he did in his life were to aid the cause of the negro. For many of his contemporaries, freeing the slaves took the level of a theoretical creed, which they hoped to implement. Franklin, however, acting like the scientist who sees theories producing experiments, felt that to talk of freeing the slaves was not enough. Experience showed that negroes were not the equal of whites, and anyone could observe that "negroes, who are free [and] live among the white people . . . are generally improvident and poor." How could such an observation be reconciled with the doctrine that all men are equal? The answer again must lie in experience. Franklin tells us that free negroes are not by nature "deficient in natural understanding," but suffer because they "have

not the advantage of education." Hence Franklin advocated not only the freeing of negro slaves, but the establishment of schools in which negroes could learn trades and become useful members of society. What he said, in effect, was: Let us educate the negroes and see whether they will not then be able to do the work of whites. This attitude reminds us of the words he wrote when he conceived that lightning is an electrical discharge: "Let the experiment be made."

Many of Franklin's contemporaries respected the Constitution they had framed because of its lofty sentiments and high ideals, because it embodied the best practices of all other governments with original features, or even because it seemed to them to represent on the behavioristic level the best features of Newtonian machines. Franklin disagreed with many aspects of the Constitution, but the feature that made it acceptable to him was the provision for amendment on trial, the possibility that in the light of actual experience alterations could be made, just as scientific theories are modified by the experiments that they suggest. I am, therefore, convinced that from Franklin's point of view the greatest experiment to which he had ever been party was not the analysis of the Leyden jar, the examination of electrification in clouds, or any of the other laboratory experiments which won him international fame, but the test as to whether a new republic, governed wisely and justly according to principles that could be adapted to changing conditions, could survive in this world.

Dispersive Infrared Analyzer.—A new, continuous infrared dispersive-type analyzer designed to continuously monitor and control liquid and gaseous process streams has been developed by Beckman Instruments, Inc., Fullerton, Calif.

The Model 176 Dispersive Infrared Analyzer is especially suited for pilot plant operation because of its versatility and easy adaptability in determining material balances and overall yields.

Another important application of the new instrument is in controlling the product purity from a fractional distillation column where its use enables greater throughput and more uniform product quality, for example, the analysis of styrene and ethyl benzene that are precisely separated in one of the steps in the manufacture of synthetic rubber.

The Model 176 combines the features of a precise, highly sensitive laboratory spectrophotometer with the heavy duty dependability of a commercial instrument. The instrument's dispersive design is based on that developed by Herscher and Wright of the Dow Chemical Co. which uses a prism-slit optical arrangement and makes for applicability to mixtures that absorb at varying wavelengths along with ease of adjustment to new problems.

The Model 176 is made up of three basic components—the detector, amplifier and recorder. The detector, a single beam spectrometer with slit width and wavelength adjustment controls, is enclosed in a rugged, explosion-proof case. A double wavelength attachment that can continually or selectively alternate the wavelength setting between two fixed wavelengths and equips the instrument to monitor two different components in a single process stream is available.

The amplifier can be separated by distances up to 300 feet from the detector. The recorder can be either a modified strip chart or circular chart type.

Performance of the new instrument includes photometric accuracy to within 1 per cent transmission while drift is less than 1 per cent a day.

Oxidant Recorder.—Now in production is the new Beckman Oxidant Recorder—an instrument developed for municipal air pollution studies but having other important uses.

These include environmental testing of products affected by air pollution such as rubber, plastics and agricultural crops and the monitoring of atmospheric industrial wastes.

Developed originally by the Stanford Research Institute, the instrument is now being used as the primary monitor to indicate smog levels in the Los Angeles County Air Pollution Control District. A total of 12 Oxidant Recorders are strategically placed throughout the District to monitor air and it is from their readings that smog alerts are called.

The Beckman Oxidant Recorder accurately measures oxidant concentrations as low as 2 parts per hundred million—and records these minute concentrations on a strip-chart recorder that has an automatic zero reading once every 24 hours.

Oxidizing materials in the air release free iodine in a buffered solution of potassium iodine and this solution is measured colorimetrically. After being measured the solution is returned to a main reservoir where it is reused since a carbon filter removes all free iodine.

Range of the instrument is 0 to 80 parts per hundred million ozone equivalents and can be extended. Accuracy is approximately 2 parts per hundred million.

THE LOGICAL DESIGN OF AN IDEALIZED GENERAL-PURPOSE COMPUTER *

BY

ARTHUR W. BURKS [1] AND IRVING M. COPI [1]

PART I [2]

1. INTRODUCTION

Any design for a general-purpose digital computer must be governed by considerations of two different kinds. The first are concerned with the purely logical (memory and truth-functional) operations to be performed. The second pertain to the physical features of the particular devices used to realize those logical operations. It follows that not all of the complexity of a computer is due to the complexity of the logical operations it performs. Much of the complexity of such machines—and of their designs—is necessitated by the peculiarities and limitations of the physical equipments specified. The usual design does not sufficiently distinguish between what is required by logic and what is necessitated by physical considerations. Often, as a result, neither the total design nor the "logical" design is rigorously formulated, although logic itself is an intrinsically rigorous subject.

Our aim in the present paper is to present in a rigorous manner a design for a complete general-purpose digital computer which will show its "pure" logical structure in abstraction from the requirements of equipment. That is, it will show what is logically required for a general-purpose computer, as distinguished from what is required physically. Any actual computer must, of course, be built subject to the engineering techniques currently available, but those techniques change rapidly with technological progress, and it is desirable for the machine designer to separate in his mind those features of his machine which result from the logical nature of the operations to be performed and those which derive from the physical nature of the components used to realize these operations.

The idealized computer presented herein is patterned in a general way after the machine described in (1).[3] To keep the presentation within a limited scope without sacrificing rigor and completeness of design we have devised an instruction language which, while completely

* The writing of this paper was done under the sponsorship of the Burroughs Corporation, Research Center, Paoli, Pa.

The logical design and analysis are primarily the work of the first author (A.W.B.) and the exposition is largely the work of the second author (I.M.C.). Thanks are due to R. L. Cartwright and G. W. Patterson for helpful criticisms and suggestions.

[1] Department of Philosophy, University of Michigan, Ann Arbor, Mich.

[2] Part II will appear in this JOURNAL for April, 1956.

[3] The boldface numbers in parentheses refer to the references appended to Part II of this paper.

general-purpose, is more rudimentary than the instruction languages used in today's machines. The simplifications gained thereby, together with additional simplifications resulting from the idealized character of the machine, are considerable. The net result is that our design for a completely general-purpose computer is much easier to understand than the usual one. Hence our presentation should have pedagogical as well as theoretical value.

The present paper is a continuation of (2), which gives a foundational analysis of logical nets (diagrams of digital computing circuits) in general. The structure of our idealized general-purpose computer is here represented by a particular kind of net studied in (2), the well-formed net.

2. THE COMPUTER AND ITS PARTS

We need first to specify the main parts of our automatic computing machine and how they communicate with one another.

The machine must be able to store both numbers and instructions to perform specified operations on them. Hence one part needed is the *storage*. In our machine it is divided into a parallel storage and a serial storage; the latter may be regarded as a high-speed input-output device. The parallel storage is in turn divided into 4096 storage bins, bin 0, bin 1, bin 2, $\cdots$, bin 4095, whose numbers constitute the **addresses** of the bins. The serial storage consists of an indefinite number of bins in series, so arranged that the content of any bin can be moved into bin 4095 of the parallel storage by a series of forward or backward shifts.

The function of the machine is to perform arithmetic operations on the numbers in its *storage*. Hence the second main part of the computer is the *arithmetic unit*. It is capable of receiving and storing one number, and combining it arithmetically with a number from the *storage*. These two parts of the computer need a path for communication. In our computer this path is the **trunk line** t, whose sixteen components $t_0, t_1, \cdots, t_{15}$ are represented by horizontal lines connecting the *arithmetic unit* and the *storage* in the lower part of Fig. 1.

We can now complete the over-all specification of the machine by stating the basic commands or instructions the computer must be able to execute. There are fourteen such instructions; all of them are listed in Fig. 2. The general meaning of each of them is clear from the foregoing, except for a_0 and a_{15} in instructions 13 and 14, respectively; a_0 is the left-most (or sign) digit of the number in the *arithmetic unit* while a_{15} is the right-most digit of that number. The precise meaning of each instruction will be elaborated at the time we describe the circuits involved in its execution.

For the machine to solve a problem it must be given a list of specific instructions, whose execution will result in the solution to the problem.

The execution of these instructions is under the direction of the *control*, the third main part of the computer, which consists of all the equipment of Fig. 1 not yet described. Instructions for the machine are stored in order in bins of the parallel storage, and, except when it is instructed to "jump" (see 12, 13, and 14 of Fig. 2), the computer executes these instructions seriatim. To this end, count must be kept of the instructions as they are executed; this function is performed by that part of the *control* called the *address counter*, which at any given time will contain the address of the bin storing the next instruction to be executed.

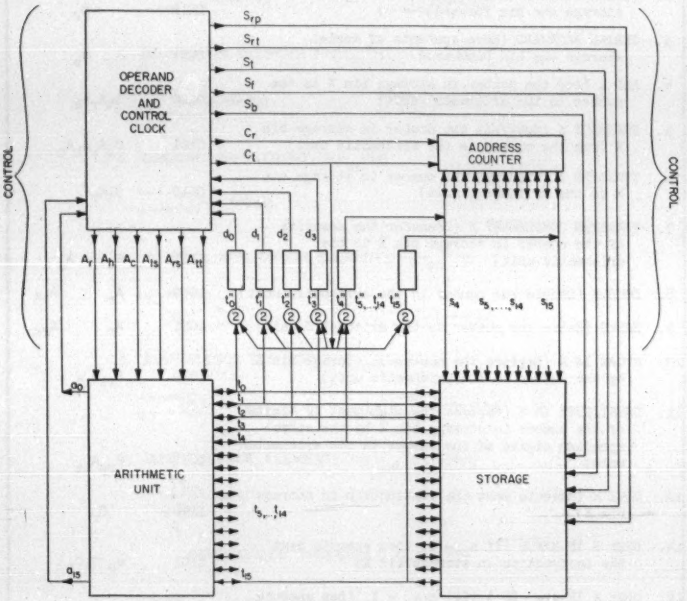


FIG. 1. Block diagram of computer.

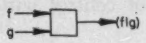
A set of instructions for the machine to execute in solving a problem is a **routine**, and every routine, however complex, must be constructed out of the primitive or basic instructions listed in Fig. 2. As each instruction emerges from the *storage* it goes to the *control*, and that part of the *control* called the *operand decoder* then stimulates the appropriate **control wires** to make the other parts of the computer perform whatever functions are required for the execution of that instruction. Eleven control wires lead from the *control* to the other parts of the machine:

six, bearing the general label A, from the *operand decoder* to the *arithmetic unit;* and five, labeled S, from the *operand decoder* to the *storage.* There are also two control wires, labeled C, which connect different

INSTRUCTION	OPERAND $d_0d_1d_2d_3$	OPERAND DECODER OUTPUT WIRES ACTIVATED AT $\tau = 2k + 1$
1. STOP	0001	
2. SERIAL FORWARD (Move contents of serial storage one bin forward)	0010	S_f
3. SERIAL BACKWARD (Move contents of serial storage one bin backward)	0011	S_b
4. ADD X (Add the number in storage bin X to the number in the arithmetic unit)	0100	$S_tA_rA_h$
5. SUBTRACT X (Subtract the number in storage bin X from the number in the arithmetic unit)	0101	$S_tA_rA_hA_c$
6. TRANSFER X (Transfer the number in storage bin X to the arithmetic unit)	0110	S_tA_r
7. TRANSFER COMPLEMENT X (Transfer the negative of the number in storage bin X to the arithmetic unit)	0111	$S_tA_r\ A_c$
8. DOUBLE (Double the number in the arithmetic unit)	1000	$A_r\qquad A_{1s}$
9. HALVE (Halve the number in the arithmetic unit)	1001	$A_r\qquad A_{rs}$
10. STORE IN X (Replace the number in storage bin X by the number in the arithmetic unit)	1010	$S_{rt}A_{tt}$
11. SUBSTITUTE IN X (Replace the rightmost 12 digits of the number in storage bin X by the corresponding digits of the number in the arithmetic unit)	1011	$S_{rp}A_{tt}$
12. OBEY X (Execute next the instruction in storage bin X)	1100	C_r
13. OBEY X IF MINUS (If $a_0 = 1$, then execute next the instruction in storage bin X)	1101	$a_0 \supset C_r$
14. OBEY X IF a_{15} IS 1 (If $a_{15} = 1$, then execute next the instruction in storage bin X)	1110	$a_{15} \supset C_r$
(At every even cycle $\tau = 2k$ when the machine is operating, $d_0 = d_1 = d_2 = d_3 = 0$, and wires S_t and C_t are activated.)		

FIG. 2. Table of instructions.

parts of the *control*, both C_r and C_t lead from the *operand decoder* and *control clock* to the *address counter*, and C_t leads also to the equipment in the center of Fig. 1 labeled t_i''. Different basic instructions cause

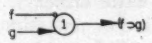


a. STROKE ELEMENT: f|g

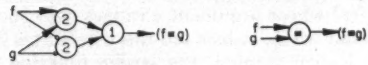
b. NEGATION ELEMENT: $\bar{f} =_{df} (f|f)$

c. DISJUNCTION ELEMENT: $(f \vee g) =_{df} (\bar{f} | \bar{g})$

d. CONJUNCTION ELEMENT: $(fg) =_{df} (\overline{f|g})$



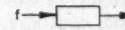
e. MATERIAL IMPLICATION ELEMENT: $(f \supset g) =_{df} (\bar{f} \vee g)$



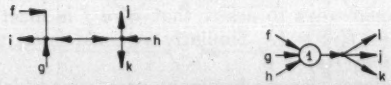
f. EQUIVALENCE ELEMENT: $(f \equiv g) =_{df} [(fg) \vee (\bar{f}\bar{g})]$

g. INEQUIVALENCE ELEMENT: $(f \not\equiv g) =_{df} [(f\bar{g}) \vee (\bar{f}g)]$

h. GENERALIZED THRESHOLD ELEMENT



i. DELAY ELEMENT: $g(0) = 0,\ g(\tau+1) = f(\tau)$ FOR $\tau = 0, 1, 2, \ldots$



j. MULTIPLE JUNCTION ABBREVIATING A MULTIPLE INPUT DISJUNCTION ELEMENT: $(f \vee g \vee h) = l = j = k$.

FIG. 3. Elements.

the *control* to stimulate different sets of control wires, as indicated in Fig. 2.

Our automatic computing machine thus consists of three main parts with communication channels between them. How these parts perform their functions will be explained in detail in Sections 4, 5 and 6. But we need first to explain the symbolism of the paper.

3. LOGICAL SYMBOLISM AND DIAGRAMS

Since our diagrams are logical nets in the sense of (2), the lines in them represent wires. Each net wire in our diagrams is in one of two **states** (0,1) at each discrete moment of time $\tau = 0, 1, 2, \cdots$. (Whenever we use τ as a time variable, it ranges over discrete moments $0, 1, 2, \cdots$ unless otherwise stipulated.) The two states 0 and 1 are complementary; they correspond to the truth values false and true, respectively. In our diagrams control wires are labeled with capital letters, other wires (information wires) are labeled with small letters from the Latin or Greek alphabets. To assert that the wire labeled f is activated or stimulated at time τ we write either f, $f(\tau)$, $f = 1$, or $f(\tau) = 1$; and to assert that it is inactive or not stimulated we write either $f = 0$ or $f(\tau) = 0$. Thus the symbols used to label wires are systematically ambiguous: any such symbol f is on the one hand a label for the wire beside which it appears, and on the other hand it is a function symbol $f(\tau)$ whose argument τ ranges over successive discrete moments of time and whose values are the wire states 0 and 1.

Our primitive logical symbol, the stroke function $\mathbf{f|g}$, means *not both f and g*, and the corresponding diagrammatic **stroke element** appears in Fig. 3*a* as a square nucleus with two **input wires** (f and g) and one **output wire** $f|g$ (as in (2)). Other logical symbols we shall use are: negation, $\bar{\mathbf{f}}$ (or alternatively $\sim\mathbf{f}$), meaning *not f;* (inclusive) disjunction, $\mathbf{f \vee g}$, meaning *f and/or g;* conjunction, $\mathbf{fg}$ (or alternatively $\mathbf{f \cdot g}$), meaning *f and g;* material implication, $\mathbf{f \supset g}$, meaning *not f or g;* equivalence, $\mathbf{f \equiv g}$, meaning *f and g, or not f and not g;* and inequivalence, $\mathbf{f \not\equiv g}$, meaning *f and not g, or g and not f.* Just as these six functions can be constructed out of the stroke function (see pp. 255–256 of (4)), so the six corresponding diagram elements can be constructed out of stroke elements, as shown in Figs. 3*b*, *c*, *d*, *e*, *f*, and *g*.[4] Each right-hand diagram in Figs. 3*b*, *c*, *d*, *f*, and *g* is a definitional abbreviation of the diagram to its left. Having introduced the symbol for negation, we have additional ways to assert that wire f is inactive at time τ: $\bar{f}$, $\bar{f}(\tau)$, $\bar{f} = 1$, and $\bar{f}(\tau) = 1$. Similarly we could assert that it is active by writing $\bar{f} = 0$ or $\bar{f}(\tau) = 0$.

The inequivalence element has many properties which make it very

[4] Some logical nets involving several primitive elements may be physically realized by devices no more complicated than those required for the physical realization of a single primitive element. For example, an electronic circuit using a single multigrid tube can realize a conjunction element.

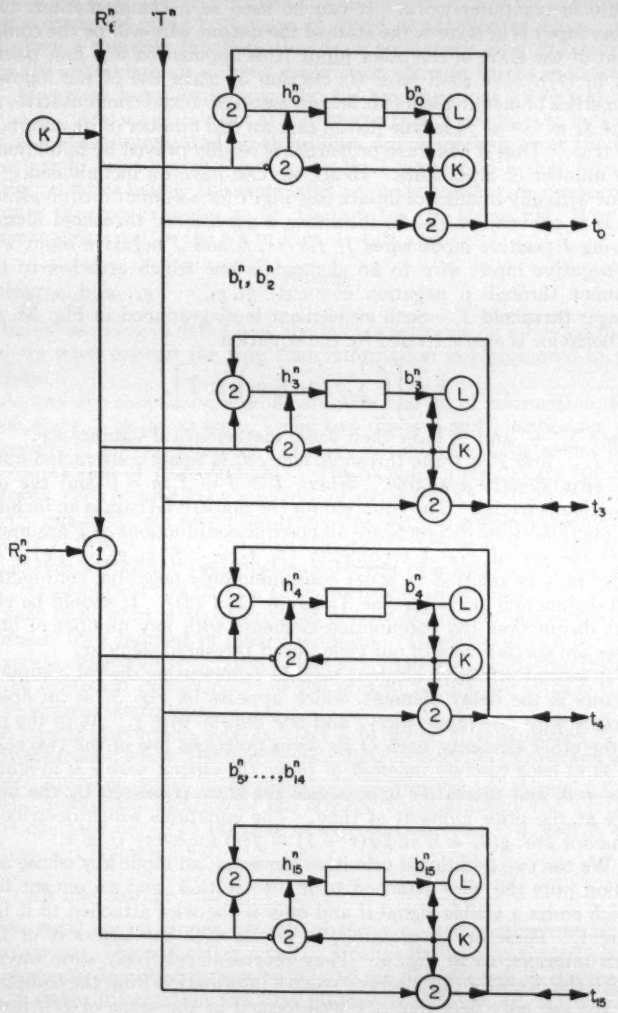


FIG. 4. Bin of parallel storage.

useful in computer work. It can be used as a **complementer**, for if either input is in state 1, the state of the output wire will be the complement of the state of the other input (this application was first pointed out in (7)). We shall later (in Section 5) make use of the following properties of inequivalence: it is both associative and commutative, and $f_1 \not\equiv f_2 \not\equiv \cdots \not\equiv f_N$ is true just in case an odd number of its arguments are true. That it has these properties is readily proved by induction on the number of arguments. Hence we can have an inequivalence element with any number of inputs (see Fig. 7 for a 3-input inequivalence).

It is convenient also to introduce a generalized **threshold element** having I positive input wires $f_1, f_2, \cdots, f_I$ and J negative input wires (a negative input wire to an element is one which attaches to that element through a negation element) $g_1, g_2, \cdots, g_J$, and a positive integer **threshold** T. Such an element is diagrammed in Fig. 3*h*, and its behavior is characterized by the equation

$$h \equiv \left[\left(\sum_{i=1}^{I} f_i + \sum_{j=1}^{J} \bar{g}_j\right) \geqq T\right],$$

where $\sum$, $+$, and $\geqq$ have their usual mathematical significance.[5] For any I, J, and $T \geqq 0$ the threshold element is easily constructed out of elements already available. Where $T > I + J$, $h = 0$ and the construction is trivial. The equation for the non-trivial case is an inclusive disjunction whose disjuncts are all possible conjunctions of T arguments from the set of $I + J$ arguments $\{f_1, f_2, \cdots, f_I, g_1, g_2, \cdots, g_J\}$, and hence may be realized by a net containing only negation, conjunction, and disjunction elements (see Theorem 12 of (2)). It should be clear that disjunction and conjunction elements with any number of input wires are special cases of our generalized threshold element.

A second primitive element used in representing digital computing circuits is the **delay element**, which appears in Fig. 3*i* as an oblong nucleus with one input wire f and one output wire g. As in the case of the other elements, each of its wires possesses one of the two states (0, 1) at each discrete moment of time: the output wire g is in state 0 at $\tau = 0$, and thereafter it possesses the state possessed by the input wire at the prior moment of time. The equations which describe its behavior are: $g(0) = 0$ and $g(\tau + 1) \equiv f(\tau)$ for every time τ.

We use two additional primitive elements: an input **key** whose activation puts the wire attached to it into state 1, and an output **light** which emits a visible signal if and only if the wire attached to it is in state 1. These are diagrammed as circles with the letters K or L in their interiors, as in Fig. 4. They represent relatively slow ways in which the operator can insert or receive information from the computer.

We use only nets that are well-formed in the sense of (2), but to simplify our diagrams we sometimes omit arrowheads and wires, as

[5] The threshold elements here defined are different from those discussed in either (5) or (6)

between the small and large circles in Figs. 3*e* and 3*g*, and we sometimes show arrowheads going both ways to avoid duplication of wires. We also allow a **multiple junction**, that is, a confluence of $n \geqq 2$ output wires, to abbreviate an n-input disjunction element in the manner of Fig. 3*j*, whose behavior is governed by the equations $(f \vee g \vee h) \equiv i \equiv j \equiv k$. And we place a dot at the intersection of two lines to indicate that the wires represented by those lines are connected, as at the left of each right-hand key in Fig. 4. Our final convention is that (except for Fig. 3) wires having the same label are understood to be connected, whether they occur in the same diagram (as the t_i's in Fig. 7) or in different diagrams (as the t_i's in Figs. 1, 4, 5, and 7).

4. STORAGE

4.1. *Information*

Before showing in detail how the *storage* performs its intended function, we must explain the way that information is represented in the machine.

At any one time a single wire can carry one **bit** of information, 0 in its off state, 1 in its on state. The two digits 0 and 1 suffice for the expression of all real numbers in binary notation, and the term "bit" is a contraction of "binary digit." The machine's vocabulary consists of **words**, each of which is a sequence of sixteen bits.[6] At any moment exactly one word will be on the trunk line, each of whose sixteen components t_i $(i = 0, 1, 2, \cdots, 15)$ carries one of the word's sixteen bits. (Whenever we use the variable i as subscript of a letter which labels a wire, it ranges over $0, 1, 2, \cdots, 15$ unless otherwise stipulated.) In the machine each word is an ordered set of wire states, and every word is expressed by a number in binary notation. These words can be used to express either numbers or instructions. Their use to express numbers will be explained in Section 5; in the present section we explain their use to express instructions.

A typical instruction, such as ADD X (4 of Fig. 2), is expressed by an **instruction** word whose first four digits $d_0d_1d_2d_3$ constitute its **operand** and whose rightmost twelve digits constitute its **address** $(X = x_4x_5 \cdots x_{15})$, which specifies the location of the storage bin containing the number to be operated on. (In the case of instructions 1, 2, 3, 8, and 9, the address part is unused.)

4.2. *Cells and Storage Bins*

We need next a circuit capable of receiving and storing one bit of information. We will call it a **cell**. A cell is easily constructed out of the elements described in Section 3. To see how the cell at the top of Fig. 4 stores information, we first observe that $h_0^n \equiv (R_i^n t_0 \vee \overline{R}_i^n b_0^n)$. Now consider what occurs at any time τ when all of the control wires

[6] Forty bits is a word length more typical of actual computers.

are in state 0. If $b_0^n(\tau) = 1$, its signal will pass through the conjunction element below h_0^n up to make $h_0^n(\tau) = 1$, whence $b_0^n(\tau + 1) = 1$, and if all control wires remain inactive, then $b_0^n(\tau + 1) = 1$ will entail $h_0^n(\tau + 1) = 1$ also, whence $b_0^n(\tau + 2) = 1$. On the other hand, if

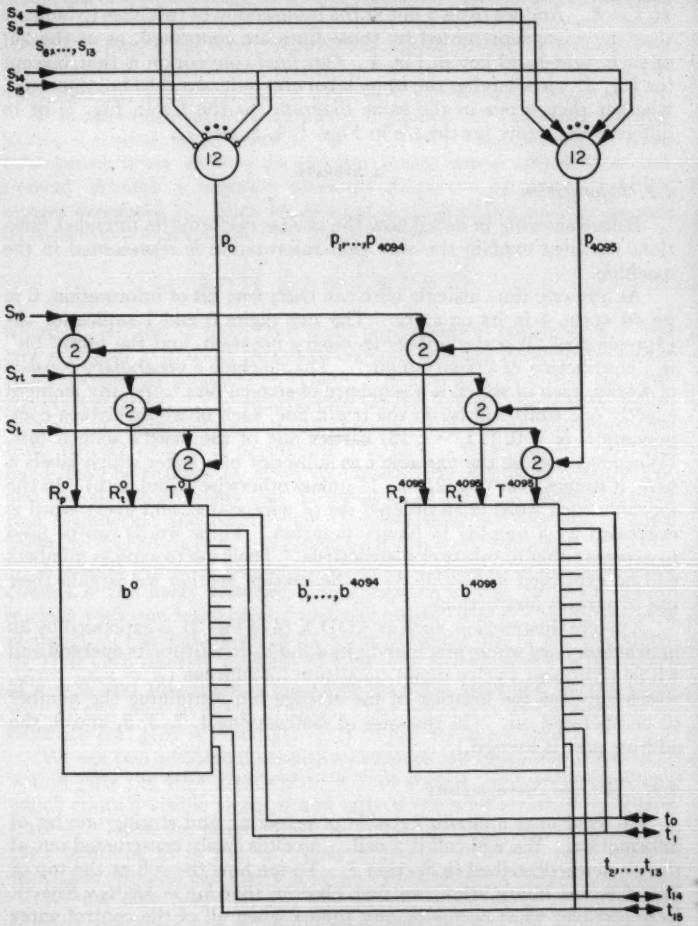


FIG. 5. Parallel storage.

$b_0^n(\tau) = 0$, no signal will reach h_0^n, and $h_0^n(\tau) = 0$, whence $b_0^n(\tau + 1) = 0$, and, if all control wires remain inactive, then $b_0^n(\tau + 1) = 0$ will entail $h_0^n(\tau + 1) = 0$ also, whence $b_0^n(\tau + 2) = 0$. Thus, if no control wires are activated during the interval in question, whatever state a cell possesses at time τ will continue to be possessed by it at times $\tau + n$ for $n = 1, 2, 3, \cdots$.

Note that each symbol b_i^n of Fig. 4 has a three-fold significance: it labels the output wire of the delay element to its left, it is a function symbol $b_i^n(\tau)$ as explained at the beginning of Section 3, and it also labels the cell within which it appears. This three-fold significance attaches to the labels of all cells within the machine: β_0^{-1} and β_0^1 in Fig. 6, a_i in Fig. 7, and a_i in Fig. 8.

With the cell as a building block, we can now proceed to construct a storage **bin**, which can receive and store a word, one bit in each cell. Figure 4 shows how this may be done.

In Section 2 we stated that the **parallel storage** was to consist of 4096 bins, $b^0, b^1, \cdots, b^{4095}$ connected in parallel. Figure 5 shows how the bins of Fig. 4 may be connected in parallel to accomplish this end.

When the machine is idle all components of the trunk are in state 0, and all cells of the bin can be cleared to state 0 manually by activating the key at the upper left corner of Fig. 4. That key's activation at such a time τ prevents any signal that may be at $b_i^n(\tau)$ from reaching h_i^n, whence $h_i^n(\tau) = 0$ and $b_i^n(\tau + 1) = 0$ regardless of the value of $b_i^n(\tau)$. Having thus cleared all cells to 0, a 1 may be inserted in any cell by activating the key at that cell's right. For if all control wires are in state 0 and the key at the left is not activated, then activating the right-hand key at time τ will cause a signal to pass through the conjunction element below h_i^n up to make $h_i^n(\tau) = 1$, whence $b_i^n(\tau + 1) = 1$, and the cell will continue to store the 1 until caused to change by the activation of the left-hand key or of some control wire. Thus the keys can be used to load each cell with its initial bit of information, and the lights provide a crude way of getting information out of the bin, since each one is visibly on or off according as its cell contains a 1 or a 0. We assume that the keys are inactive in the following discussion.

Three control wires lead to each bin, a distinct set to every bin. Figure 4 shows the nth bin and its control wires R_p^n, R_t^n, and T^n. Its ith cell b_i^n is connected to the ith component t_i of the trunk.

The control wire T^n is the **transmit** wire for bin n. When it is activated, the bit in each cell enters the appropriate component of the trunk, passing from b_i^n through the lower conjunction element onto t_i, whence $t_i \equiv T^n \cdot b_i^n$.

It is convenient to be able to alter an instruction by changing its address without modifying the operand. Hence the wiring of the first four cells of each bin is different from that of the last twelve cells, as shown in Fig. 4. The control wire R_p^n is the **partial reception** control

for bin n. It connects, by way of the disjunction element, to the last twelve cells $b_4^n, b_5^n, \cdots, b_{15}^n$. If it is activated at time τ (by instruction 11 of Fig. 2), and R_t^n is not activated, then whatever bit is on trunk component t_i ($i = 4, 5, \cdots, 15$) at time τ will flow through the upper left conjunction element of cell b_i^n onto h_i, from which it will emerge at $\tau + 1$ to occupy b_i^n, in which case $b_i^n(\tau + 1) \equiv t_i(\tau)$ for $i = 4, 5, \cdots, 15$, and $b_i^n(\tau + 1) \equiv b_i^n(\tau)$ for $i = 0, 1, 2, 3$.

The control wire R_t^n is the **total reception** control for bin n. It connects directly to the first four cells and by way of the disjunction element to the last twelve cells also. If it is activated at time τ (by instruction 10), then whatever bit is on trunk component t_i at time τ will occupy cell b_i^n at time $\tau + 1$; in this case $b_i^n(\tau + 1) \equiv t_i(\tau)$.

The storage bin's behavior is described more compendiously by the equations

$$b_i^n(\tau + 1) \equiv [R_t^n(\tau) \cdot t_i(\tau) \vee \bar{R}_t^n(\tau) \cdot b_i^n(\tau)] \quad \text{for} \quad i = 0, \cdots, 3,$$

and

$$b_i^n(\tau + 1) \equiv \{[R_t^n(\tau) \vee R_p^n(\tau)]t_i(\tau) \vee \bar{R}_t^n(\tau) \cdot \bar{R}_p^n(\tau) \cdot b_i^n(\tau)\} \quad \text{for} \quad i = 4, \cdots, 15.$$

4.3. Address Decoder

For the computer to use the information in its parallel storage, it must have some method of switching to or selecting a specified location there. Twelve binary digits suffice to specify any storage bin uniquely. The **Address Decoder** is a switching mechanism which activates the proper storage bin when it receives the twelve digit number which is the address of that bin.

The Address Decoder has 4096 distinct output wires $p_0, p_1, \cdots, p_{4095}$, each connected to a distinct storage bin of the parallel storage. Each distinct p_i is activated by a different set of twelve digits which may be carried by the Address Decoder's twelve input wires $s_4, s_5, \cdots, s_{15}$. The functional connection is accomplished through the use of 4096 threshold-12 elements, as shown in Fig. 5.[7] The same twelve input wires are connected to each of the 4096 threshold-12 elements, those connections being described by the equations:

$$p_0 \equiv (s_4 s_5 \cdots s_{14} s_{15}),$$
$$p_1 \equiv (\bar{s}_4 s_5 \cdots s_{14} s_{15}),$$
$$\cdots,$$
$$p_{4094} \equiv (s_4 s_5 \cdots \bar{s}_{14} \bar{s}_{15}),$$
$$p_{4095} \equiv (\bar{s}_4 \bar{s}_5 \cdots \bar{s}_{14} \bar{s}_{15}).$$

[7] Greater economy in the Address Decoder could be achieved by using a less straightforward design, as explained in (3).

General directions for the parallel storage are carried by control wires S_{rp}, S_{rt}, and S_t (Figs. 1 and 5), at most one of which is in state 1 at any time. Each of these control wires is connected to 4096 different conjunction elements, whose other input wires are the 4096 distinct p_i's. Since at most one of the control wires S_{rp}, S_{rt}, S_t is activated at any time, and exactly one of the Address Decoder's output wires $p_0, p_1, \cdots, p_{4095}$ is activated at any given time, there is at any given time at most one bin n for which any of the control wires R_p^n, R_t^n, T^n is activated at that time, and, if there is such a bin n, at most one of those three control wires R_p^n, R_t^n, T^n is activated at that time. The equations which describe the circuits diagrammed in Fig. 5 are of the form: $R_p^n \equiv (S_{rp} \cdot p_n)$, $R_t^n \equiv (S_{rt} \cdot p_n)$, $T^n \equiv (S_t \cdot p_n)$.

For example, in the execution of instruction 4 of Fig. 2, ADD X, the operand 0100 of that instruction causes control wire S_t to be stimulated and the address $x_4x_5 \cdots x_{15}$ enters the input wires of the Address Decoder to stimulate its output wire p_x. That stimulates T^x, the output wire of a conjunction element whose two input wires are S_t and p_x, to make the number in bin X pass onto the trunk where it is available to the *arithmetic unit*.

Here and throughout this paper we speak as if the electrical response of a circuit were instantaneous, which is not strictly accurate. For our remarks to be made unobjectionable we need only make the duration of the time interval we refer to as a "moment" sufficiently large to permit a signal to pass from any part of the machine to any other part during that interval. Our "moments" need not all be of the same duration, of course, and intervals of any different durations may lie between what we refer to as "successive moments." It should be kept in mind that the shorter the durations of these "moments" and the shorter the time lapses between them, the higher the speed of computation that can be achieved by the machine.

These remarks should suffice to indicate that the states 0 and 1 of our wires need not be pulses, but can alternatively be static states. It is, of course, part of the idealized representational function of our diagrams that they permit of either interpretation.

In practice a relatively uncomplicated physical device may correspond to a very complex logical net; no one-to-one correspondence is suggested between the elements of our diagrams and the physical components of the computing machine which realizes them. For example, our general design for the parallel storage (less the keys) can be realized physically without using separate delay lines, as by a Williams' tube cathode ray storage device which consists of many tubes and associated circuits. The delay elements in our diagrams represent the fact that information is stored, but do not represent the specific physical devices that may be used to accomplish that storage function. Our design is intended to represent the logical role rather than the physical constitu-

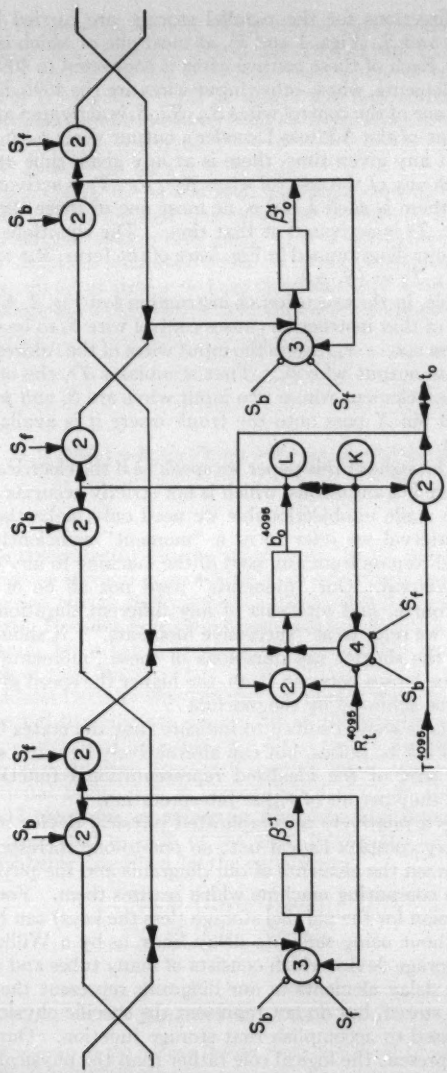


FIG. 6. Serial storage.

tion of a computer and its parts. Hence many of the details of the circuits involved in the Williams' tube storage (pulse shaper, etc.) are not represented by our diagrams. Nor is the breakdown into parts similar, for a single tube will store bits from many bins (say, 1024 of them), with the contents of a single bin distributed over sixteen different tubes.

4.4. Serial Storage

In addition to the relatively limited parallel storage already described, our computer has a theoretically infinite serial storage,[8] which supplements the parallel storage. The **serial storage** consists of sixteen parallel strings of cells, every cross section of which may be regarded as a storage bin. Our computer is so designed that exactly one storage bin belongs to both the parallel storage and the serial storage.[9] For definiteness, we specify it to be bin 4095 of the parallel storage, which must be given somewhat more complicated cells to enable it to play its dual role. In Fig. 6, which shows only three cells of the topmost string, the middle cell diagrammed belongs to this special bin. Each string is to be thought of as extending indefinitely in both directions.

It is clear from the diagram that if neither of the control wires S_b, S_f is activated, every bin of the serial storage save b^{4095} continues to store whatever information it contains, and if $R_p^{4095} \equiv R_t^{4095} = 0$, then b^{4095} also continues to store whatever information it contains. Now, if control wire $S_b(S_f)$ is activated at time τ, the internal circulation or storage of information in each cell is interrupted at the threshold-3 element in each ordinary cell and at the threshold-4 element in each special cell of the shared bin, and any bit of information in each cell will pass up the wire to the right of its delay element, through the left (right) conjunction element above, and down to the input wire of the delay element of the cell to its left (right).

If we assign the labels $\cdots, \beta_i^{-2}, \beta_i^{-1}, \beta_i^{0}, \beta_i^{1}, \beta_i^{2}, \cdots$ to the cells of the serial storage, where β_i^{0} is b_i^{4095}, the behavior of the serial storage is described by the expression

$$\bar{R}_p^{4095} \cdot \bar{R}_t^{4095} \supset \{\beta_i^{n}(\tau + 1) \equiv [S_b(\tau) \cdot \beta_i^{n+1}(\tau) \vee S_f(\tau) \cdot \beta_i^{n-1}(\tau) \vee \bar{S}_b(\tau) \cdot \bar{S}_f(\tau) \cdot \beta_i^{n}(\tau)]\},$$

where $n = \cdots, -2, -1, 0, 1, 2, \cdots$.

[8] An actually infinite serial storage is not a net in the sense of (2). But the serial storage is so connected to the machine that the whole net has the property that at any arbitrary time only a finite number of its wires have changed from their initial states. Hence at no time is the net presumed to contain an infinite amount of information, and it can therefore be regarded as a finite but indefinitely expansible net.

[9] The serial storage may be realized by a magnetic tape (or set of tapes) with sixteen parallel channels of information. Here a single cell corresponds to a region of the tape which is or is not magnetized, and the operation of shifting the contents of the bins forward or backward is realized by moving the tape mechanically. On this interpretation the serial storage represents a relatively rapid way in which information can pass between the computing machine and its operator.

If a word located in an ordinary bin of the serial storage is to be used, the contents of the serial storage must be shifted backward or forward until that word occupies the special bin b^{4095}, from which it is immediately available to the computer as described in Section 4.2. Hence the greater capacity of the serial storage is purchased, so to speak, at the expense of ready availability of its contents.

At this point the analogy should be noted again between our diagrammatic conventions and the process of definition. Just as a single term can be introduced as an abbreviation for a whole sequence of other terms, so some parts of our diagrams are to be understood as definitional abbreviations for other, more complicated parts. We have already pointed out that each right-hand diagram in Figs. 3*b*, *c*, *d*, *f*, and *g* is a definitional abbreviation of the diagram to its left. Similarly, in Fig. 5 each box b^n is to be understood as a shorthand notation for the more detailed diagram of storage bin b^n presented in Fig. 4. (Both, it should be noted, are connected to the same three control wires and the same sixteen components of the trunk.) And the block labeled *storage* in Fig. 1 is a definitional abbreviation of the complete net whose parts are represented in Figs. 5 and 6, that is, of the combined and interconnected parallel and serial storages.

(To be continued.)

ORIGIN OF THE INVENTION OF STEEL EXTRUSION BY GLASS LUBRICATION

BY

JACQUES SEJOURNET[1]

In 1935, at the request of my father-in-law who was about to retire, I had agreed to give up my position as engineer with Renault, the French automobile manufacturer, to become Manager of his company, the Comptoir Industriel d'Etirage & Profilage de Metaux.

It was a small company specializing in the production of sections by cold-drawing. The equipment included draw benches and a small 600-ton extrusion press working non-ferrous metals—copper, brass and aluminum. The shops as well as the equipment were old and it was obvious that my activity was going to be in the direction of modernizing the plant.

Within a few years, I became thoroughly familiar with the details of all the elements of the company's various operations. I was particularly interested in questions concerning tools which represented the largest item of our cost. I observed that no systematic research whatever had been undertaken in this field and I decided to get in touch with a steelmaker to improve this factor. This is the origin of my relationship with the Ugine Steelworks and M. Labataille who was in charge of the Tool Steel Department of that company. This co-operative effort led to fruitful results.

At this same time, the Ugine Steelworks' Laboratory was studying new types of heat-resisting steels and had developed a new grade with excellent hot-working properties. Ugine had, for many years, been interested in steel extrusion and it occurred to the technicians of that company to try to see whether the new grade would render possible successful manufacture of dies for the severe conditions of steel extrusion.

M. Labataille thought at once of Comptoir d'Etirage because it presented the advantage of a small company, whose administrative organization was small enough to permit expediting the research under consideration. In addition, the extrusion press was in Paris, thus making technical co-operation easier.

Negotiations in connection with the research agreement lasted quite some time, but an agreement was finally signed, providing for: (*a*) expenses to be borne equally by the two companies; (*b*) joint ownership of eventual patents; and (*c*) parting of the commercial field in case of a successful conclusion—tubes for Ugine, sections for Comptoir.

[1] Directeur General, Comptoir Industriel d'Etirage & Profilage de Metaux, Paris, France. M. Sejournet was awarded a John Price Wetherill Medal at The Franklin Institute Medal Day Ceremonies, October 19, 1955, in recognition of his invention of the process described in this paper.

Then, just as my father-in-law was about to retire, the war suddenly broke out.

We first went through a restless period for armament purposes; then came the German occupation, the truce and the practical standstill of all activities. After several months elapsed, it looked as if the Company's activities would not be great enough to occupy the time of all of its staff. I had been the last one to join the company and I offered to try to find another job, but I was asked to stay with the Company. I remembered then the agreement we had signed with Ugine so many years before, to develop steel extrusion, and I offered to tackle this particular problem.

I set to work at once and extruded a few billets with makeshift equipment to get an idea of the difficulties encountered in connection with this problem. They proved to be very serious difficulties, indeed! Only two billets were extruded and the conclusion of my report on these tests read as follows: "We think that the lubrication problem will be of considerable importance in the hot extrusion of steel. . . . Further, we consider that tearing of the metal of the die by that of the extruded bar is partly due to a high friction coefficient."

On October 16, 1940, I sent to Ugine a first program of tests which provided for the extrusion of 20 carbon steel billets into round bars, 1 in. to 2 in. in diameter. The first series of tests was run on October 30, 1940 with M. Labataille's assistance. These tests showed that steel can be easily worked by extrusion, but confirmed the very great difficulties encountered, namely: (*a*) scratches on the dies resulting from seizing of the extruded metal on to the metal of the die; (*b*) scratches on the extruded bars resulting from particles of scale from the slug adhering to the die; and (*c*) difficulties in the ejection of discards and the sawing off of the bars.

To face such difficulties, I decided first to apply to the die all the known lubricants, of animal, vegetable or mineral origin: grease, tallow, oils, talc, pitch, graphite, borax. To avoid the influence of scale on the billets we decided to build a salt bath to heat the billets without oxidation. However, economic conditions during the German occupation did not permit the rapid construction of this furnace, and in order not to delay our tests, we decided to try to modify the nature of the scale by rolling the billets either in charcoal powder, or in borax, prior to introducing them into the container of the extrusion press. Additionally, we undertook some modifications in our press in order to facilitate ejection of the discard and sawing of the bars.

In June of 1941 a new series of tests took place. The first experiments were run with scaled billets, lubricating the dies with the various lubricants under consideration, without any successful result. Then, we tried to descale the billets, the first trial being with charcoal powder; the result was even worse. We next tried a mixture of charcoal and

borax without any improvement. However, upon examination of the pressure curves, I noticed that the extrusion pressure had considerably decreased and that it looked as if the sodium borate lubricated the advance of the billet inside the container. This observation was immediately confirmed using borax alone.

However, the most important problem that remained to be solved was the wear of the dies.

Following our observations concerning the role of sodium borate we naturally tried to utilize that compound to lubricate the die. The first difficulty came from the fact that borax is supplied commercially in powder form; a certain amount of powder needed to be applied on the die which of course is placed vertically in the press. The idea occurred to me of using for the purpose small paper bags filled with borax powder, placing them in the container against the die. This was the main idea that led progressively to the final solution.

The results obtained were entirely different from the previous ones: the scratches on the extruded bars disappeared almost entirely, the die-wear decreased and the extrusion pressure decreased substantially also.

However, the use of bags of powder was inconvenient and other methods of application were considered. Borax was then mixed with other substances, namely, oils and greases and the results again were bad. Also, it was noticed that the presence of the paper bags was detrimental and we were led to think that the solution of solid borax plates was the only one possible commercially.

Unfortunately, I was confronted with a major difficulty: it was very difficult to obtain fused borax plates that would not be brittle. The plates obtained would give good results but generally shattered merely on contact with the hands and their utilization was very inconvenient.

Just at that time I happened to read a book on the physical and chemical properties of glasses and I found that numerous compositions of glasses contain sodium borate. It occurred to me to get in touch with glassmakers and to ask them how to make non-brittle borax plates. The advice given to me was to melt, with the borax, during the heating operation, some silica, lime, soda and alumina. The products obtained when melting this mixture are easier to pour and are not brittle during the cooling operation.

A few plates were made and the results obtained were remarkable: the whole surface of the die was coated with a uniform film of lubricant, while the die-land remained perfectly smooth and shiny; the extruded metal did not adhere in any place to the die and the extruded bar was coated with a thin layer of lubricant and was smooth under this layer. It seemed as if, at no time, had there been any contact between the billet, the extruded bar and the tools. After extrusion, the temperature of the die was only slightly higher than before and it soon became obvi-

ous that it was no longer necessary to use the Ugine heat-resisting steel for the manufacture of dies.

During the course of a series of extrusion tests with the plates manufactured from the mixture of borax, silica, lime, soda and alumina, we suddenly found that our supply was exhausted as we had not made a sufficient number of plates. The results were good and we were very anxious not to stop in the middle of our research program. The similitude of composition of our plates and ordinary glass suddenly occurred to me and I asked the foreman of the maintenance shop to cut at once discs from window-glass. It happened that this man had worked in the past at a glazier's and it was an easy job for him to cut these discs. The results were at once remarkable, better and more regular than those previously obtained, and from that day we could consider that the basic elements of the commercial solution had been found.

There still remained to be developed the extrusion of tubes, and this was difficult on account of the seizing of the billets on the mandrel. Naturally, we thought of slipping the mandrel inside a glass tube to protect it in a manner similar to that used with the die. Unfortunately, the war was still on. We were out of everything and it was impossible to find glass tubes in the trade. A few tubes of Pyrex that a friend had kindly given to me gave disappointing results on account of their high melting point. It occurred to me to buy a few lamp chimneys, this manufacture having been taken up again in France on account of the lack of electric light at that time, and I could easily find some. The results proved to be excellent and confirmed our ideas on the hot lubrication under pressure.

The basic elements had been found; the commercial utilization remained to be developed. My collaborators set to that task and I thank them very heartily for the considerable work they performed under the very difficult circumstances that prevailed during the war and post-war periods.

It required twelve years of strenuous work for making the initial discovery of a new commercial process of working of metals, that now may be compared to the oldest processes that have existed for a hundred years or more.

VIBRATIONS OF A RECTANGULAR PLATE WITH DISTRIBUTED ADDED MASS *

BY

HIRSH COHEN [1] AND GEORGE HANDELMAN [1]

ABSTRACT

The problem studied is that of determining the lowest frequency of vibration of a rectangular plate, simply supported on two edges and free on the other two, and carrying a rigid mass of finite width running completely across the plate. Appropriate minimum principles are developed and approximate frequencies computed. The frequency may be either less or greater than that of the unloaded plate depending on the ratio of the physical parameters.

1. INTRODUCTION

The problem to be considered is that of determining the lowest frequency of vibration of a rectangular plate to which a rigid mass of finite area has been rigidly attached. The plate is taken to be simply supported along two opposite edges and free on the other two. The mass is rectangular in shape, centrally located, and runs completely across the plate in a direction parallel to the simply supported edges (see Fig. 1).

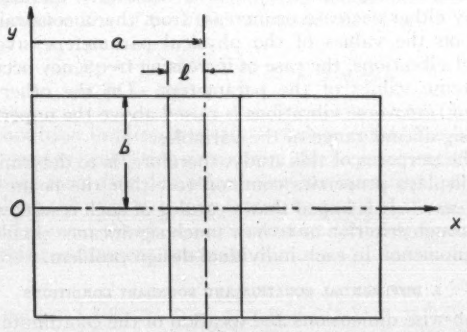


FIG. 1.

This particular question is one of a series under study to determine the effects produced on vibration when added mass is assumed to occupy a finite area. It is recognized that the model in question is far removed from the practical problem of calculating the effects of attaching masses

* This research has been partially supported by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.

[1] Department of Mathematics, Rensselaer Polytechnic Institute, Troy, N. Y.

to vibrating systems, for not only have the geometries of the plate and mass been taken in very simple form but the rigid mass has been assumed to be rigidly attached throughout its area. Such a study seems to be more than merely academic, however, since previous special cases indicate that it is very difficult to draw a general conclusion as to what the effect of such a rigidification will be.

The general nature of the question can be seen from the following considerations. According to the usual Rayleigh approach, the lowest frequency of a vibrating system is given by the ratio of the potential energy to the kinetic energy. The addition of mass increases the kinetic energy which in turn would tend to lower the fundamental frequency. On the other hand, the rigidification produced by the mass covering a finite area, acts as a constraint which increases the potential energy and hence tends to increase the frequency of the system. The question then arises as to which of these effects is dominant and furthermore whether there are any values of the physical parameters for which the frequency remains the same as that of the unconstrained system.

Kornhauser and Mintzer (1) [2] initiated this study by considering the case of a circular membrane loaded by a concentrically placed disc. They found that the frequency is raised, in contrast to the usual Rayleigh results for the addition of a point mass. Cohen and Handelman (2) considered the same problem for the beam and found that in both the case of longitudinal as well as transverse vibrations the frequency may either decrease or increase from the unconstrained system depending on the values of the physical parameters involved. For longitudinal vibrations, the case of increasing frequency occurs only for rather extreme values of the parameters. On the other hand, the frequency of transverse vibrations is raised above the unperturbed case for a very significant range of the variables.

One of the purposes of this study, therefore, is to determine whether the plate displays properties common to either the beam case or the membrane case. It is hoped that a catalog of such results will give the engineer a rough criterion as to how much significance should be placed on this phenomenon in each individual design problem.

2. DIFFERENTIAL EQUATION AND BOUNDARY CONDITIONS

The plan-wise dimensions and location of the coordinate system are shown in Fig. 1. The edges $x = 0$ and $x = 2a$ are simply supported, whereas the edges $y = \pm b$ are free. The added mass is assumed to be rigidly attached over the portion of the plate $a - l \leq x \leq a + l$, $-b \leq y \leq b$. The thickness of the plate material will be denoted by h and that of the plate plus added mass by t. In addition, ρ will denote the mass per unit volume of the plate and ρ' that of the plate plus additional mass. As is customary, Young's modulus is E and Poisson's ratio, ν.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

The differential equation for the vertical deflection $w(x,y)$ of the plate is the usual one (see Timoshenko (3))

$$\Delta\Delta w = \mu^2 \frac{\rho h}{D} w, \tag{1}$$

where Δ denotes the Laplacian operator, μ the circular frequency found by eliminating the time dependent factor $\exp i\mu t$, and D is the plate flexural rigidity defined by

$$D = \frac{Eh^3}{12(1 - \nu^2)}.$$

The boundary conditions on the simply supported edges can be reduced to

$$w(0,y) = w_{xx}(0,y) = w(2a,y) = w_{xx}(2a,y) = 0, \tag{2}$$

and those describing the free edges are

$$\left.\begin{aligned} w_{yy}(x, \pm b) + \nu w_{xx}(x, \pm b) &= 0 \\ w_{yyy}(x, \pm b) + (2 - \nu) w_{xxy}(x, \pm b) &= 0 \end{aligned}\right\} \quad \begin{matrix} 0 \leqq x \leqq a - l, \\ a + l \leqq x \leqq 2a. \end{matrix} \tag{3}$$

It will be assumed that the mode of vibration corresponding to the lowest frequency is symmetric about the center line $x = a$. Hence along the junction line of the rigid mass and the plate

$$\left.\begin{aligned} w_y(a - l,y) &= 0 \\ w_x(a - l,y) &= 0 \end{aligned}\right\} \quad -b \leqq y \leqq b. \tag{4}$$

The first condition implies that $w(a - l,y) = \text{const.}$ for $-b \leqq y \leqq b$. The final boundary condition arises from the requirement that the total effective shear force (see Timoshenko (4)) transmitted by the plate to the mass along the edge $x = a - l$ must be equal to the product of one half the added mass times its acceleration. Utilizing boundary conditions (4), this requirement becomes

$$\int_{-b}^{b} w_{xxx}(a - l,y)dy = -\mu^2 \frac{2blt\rho'}{D} w(a - l,y), \quad -b \leqq y \leqq b. \tag{5}$$

A complete solution of the problem then requires finding a function $w(x,y)$ and corresponding eigenvalue μ^2 which satisfy the differential equation (1) and all the boundary conditions (2) through (5).

3. MINIMUM PRINCIPLE

A brief inspection of the eigenvalue problem posed in Section 2 will show that it is not susceptible to a solution of the simple product type. The difficulty stems from the boundary conditions (4) and (5). It is

therefore appropriate to consider the minimum principle which is valid for the lowest eigenvalue.

If λ^2 and $u(x,y)$ are any eigenvalue and eigenfunction of the differential equation (1) satisfying boundary conditions (2) through (5), it can be shown that

$$\lambda^2 = \frac{D\int\int_I [(u_{xx}+u_{yy})^2 + 2(1-\nu)(u_{xx}u_{yy}-u_{xy}^2)]dxdy}{\int\int_I \rho h u^2 dxdy + 2blt\rho'[u(a-l,y)]^2}, \quad (6)$$

where the double integration is taken over I, half of the unrestrained plate, that is, $0 \leqq x \leqq a-l$, $-b \leqq y \leqq b$. Equation 6 is derived in the usual manner by multiplying Eq. 1 by u and integrating over I. Suitable integration by parts yields Eq. 6. The details will not be given here since they will be similar to those carried out in the proof of the minimum principle.

Let W be the class of all functions $w(x,y)$ which satisfy the following requirements: (*a*) w has continuous fourth partial derivations in I, (*b*) $w(0,y) = 0$, (*c*) $w_y(a-l,y) = 0$, and (*d*) $w_x(a-l,y) = 0$. It will be shown that if μ^2 is the solution to the following minimum problem and w is the minimizing function,

$$\mu^2 = \min_W \frac{D\int\int_I [(w_{xx}+w_{yy})^2 - 2(1-\nu)(w_{xx}w_{yy}-w_{xy}^2)]dxdy}{\int\int_I \rho h w^2 dxdy + 2blt\rho'[w(a-l,y)]^2}, \quad (7)$$

then μ^2 is the lowest eigenvalue and w the corresponding eigenfunction of the differential equation (1) satisfying all of the boundary conditions (2) through (5).

It is important to note that the admissible functions do not have to satisfy all of the boundary conditions of the original problem, but the minimizing function will satisfy the remaining boundary conditions as natural boundary conditions. In particular, $w_{xx}(0,y)=0$, $w_{xx}(2a,y)=0$, Eq. 3 and Eq. 5 are natural boundary conditions for the problem. This means that upper bounds for the lowest frequency can be found by using functions which only satisfy those boundary conditions prescribed by the definition of the class W, thus easing the computational problem considerably.

The proof of the principle follows along standard lines and hence only a brief sketch of it will be given. Let w be the minimizing function and μ^2 the corresponding minimum value. Consider another admissible function $u(x,y)$ defined by

$$u(x,y) = w(x,y) + \epsilon\eta(x,y),$$

where ϵ is an arbitrary parameter. If u is substituted into the right hand side of Eq. 7, it will yield a value in excess of μ^2. Multiplying through by the denominator this statement yields an inequality of the following form

$$A(w) + \epsilon B(w, \eta) + \epsilon^2 A(\eta) \geqq 0,$$

where the dependence of the coefficients on the functions w and η is as indicated. It is seen that the first coefficient $A(w)$ vanishes since it is the condition that μ^2 and w satisfy the minimum problem (7).

Thus the inequality reduces to

$$\epsilon B(w,\eta) + \epsilon^2 A(\eta) \geqq 0$$

which must be valid for arbitrary ϵ. Consequently, the coefficient of the linear term in ϵ must be zero, or $B(w,\eta) = 0$. If this term is written out in full, it is found that

$$\begin{aligned} D \int\int_I & [2(w_{xx} + w_{yy})(\eta_{xx} + \eta_{yy}) \\ & - 2(1 - \nu)(w_{xx}\eta_{yy} + w_{yy}\eta_{xx} - 2w_{xy}\eta_{xy})]dxdy \\ & - \mu^2 \int\int_I 2\rho h w \eta dxdy - 4\mu^2 blt\rho' w(a - l,y)\eta(a - l,y) = 0. \quad (8) \end{aligned}$$

If Eq. 8 is integrated by parts and account taken of the boundary conditions which η must satisfy, there results

$$\begin{aligned} \int\int_I & [D\{2w_{xxxx} + 4w_{xxyy} + 2w_{yyyy}\} - 2\mu^2\rho h w]\eta dxdy \\ & + D \int_{-b}^{b} [2(w_{xx} + w_{yy}) - 2(1 - \nu)w_{yy}]\eta_x \Big|_0 dy \\ & - D \int_{-b}^{b} [2(w_{xxx} + w_{yyx} - 2(1 - \nu)w_{yyx}]\eta \Big|^{a-l} dy \\ & + D \int_0^{a-l} [2(w_{xx} + w_{yy}) - 2(1 - \nu)w_{xx}]\eta_y \Big|_{-b}^{b} dx \\ & - D \int_0^{a-l} [2(w_{xxy} + w_{yyy}) + 2(1 - \nu)w_{xxy}]\eta \Big|_{-b}^{b} dx \\ & - 4\mu^2 blt\rho' w(a - l,y)\eta(a - l,y) = 0. \quad (9) \end{aligned}$$

Here the vertical line with suffixes denotes the boundaries over which the line integrals are to be taken.

Now the function η is perfectly arbitrary provided only that it possess the required continuity properties and satisfy the boundary conditions of the class of functions W. Hence, if η and its normal derivatives are taken to be zero on the boundary, but otherwise arbitrary

in I, the vanishing of the first integral in Eq. 9 implies that

$$D\Delta\Delta w = \mu^2 \rho h w. \tag{10}$$

The boundary integrals may now be examined in turn. If $\eta_x(0,y)$ is taken to be arbitrary and the values of η and its derivatives are taken to be zero on the remaining boundaries, the first line integral yields

$$w_{xx} + w_{yy} - (1 - \nu)w_{yy} = 0, \quad (x = 0).$$

By virtue of requirement (b) on the class W, this becomes

$$w_{xx}(0,y) = 0. \tag{11}$$

In like fashion, if $\eta(x,\pm b)$ and $\eta_y(x,\pm b)$ are taken to be arbitrary in turn, there results

$$\begin{aligned} w_{yy}(x,\pm b) + \nu w_{xx}(x,\pm b) &= 0, \\ w_{yyy}(x,\pm b) + 2(1 - \nu)w_{xxy}(x,\pm b) &= 0. \end{aligned} \tag{12}$$

Finally, it should be noted that $\eta(a - l,y)$ can only take on arbitrary constant values. Hence

$$D\int_{-b}^{b} [w_{xxx} + w_{yyx} - (1 - \nu)w_{yyx}]\Big|^{a-l} dy = -2\mu^2 bt\rho' w(a - l,y).$$

Requirements (c) and (d) on the class W then reduce this equation to

$$D\int_{-b}^{b} w_{xxx}(a - l,y)dy = -2\mu^2 blt\rho' w(a - l,y). \tag{13}$$

It is thus seen, by comparing Eqs. 10 through 13 with Eqs. 2 through 5, that the minimizing function w and the minimum value μ^2 are actually an eigenfunction and eigenvalue of the differential equation.

It only remains to show that μ^2 is actually the lowest eigenvalue. Suppose that λ^2 were the lowest eigenvalue and u the corresponding eigenfunction, that is, $\lambda^2 \leqq \mu^2$. Now u is a function which belongs to W. Therefore, inserting it in the right hand side of Eq. 7 will yield an upper bound for μ^2. On the other hand, Eq. 6 shows that this upper bound is precisely λ^2. Hence $\mu^2 \leqq \lambda^2$, and finally $\lambda^2 = \mu^2$. Therefore, the solution to the minimum problem yields the lowest eigenvalue of the problem.

4. APPROXIMATE FREQUENCY OF A RECTANGULAR PLATE

In order to obtain an approximate lowest frequency, the following trial function has been used in the minimum principle of Section 3:

$$w = \sin\frac{\pi x}{2(a-l)} + Ab^3\left(\cos\frac{\pi y}{2b}\right)x(x-a+l)^2. \tag{14}$$

The parameter A is left free to be determined by the minimizing condition. It should be noted that the first term in Eq. 14 is the solution for a beam of half length $a - l$ to which no mass has been added. Inserting this function in Eq. 7 one obtains the following expression for the non-dimensional quantity λ.

$$\lambda = \frac{a^4\rho h\mu^2}{D} = \frac{\mathfrak{A} + \mathfrak{B}\bar{A} + \mathfrak{C}\bar{A}^2}{\mathfrak{D} + \mathfrak{E}\bar{A} + \mathfrak{F}\bar{A}^2}. \tag{15}$$

Here $\bar{A} = Aa^6$, and the coefficients are given by

$$\mathfrak{A} = \frac{\pi^4}{16R(1-k)^3}, \quad \mathfrak{B} = \frac{16}{R^4}\left(1-\frac{3}{\pi}\right)[1 + R^2\nu(1-k)^2],$$

$$\mathfrak{C} = \frac{1}{R^3}(1-k)^3\left[\frac{4}{R^4} + \frac{\pi^4(1-k)^4}{1680} + \frac{\pi^2(1-k)^2}{15R^2}\right],$$

$$\mathfrak{D} = \frac{1}{R}\left[1-k+\frac{2k}{m}\right], \quad \mathfrak{E} = \frac{256}{\pi^4R^4}(1-k)^4\left(1-\frac{3}{\pi}\right),$$

$$\mathfrak{F} = \frac{(1-k)^7}{105R^7},$$

where $l/a = k$, $a/b = R$, $\rho/\rho' = m$ and for simplicity t has been set equal to h.

Applying the minimizing condition, the approximate non-dimensional frequency is found to be:

$$\lambda = \frac{\mathfrak{E}\mathfrak{B} - 2(\mathfrak{D}\mathfrak{C} + \mathfrak{A}\mathfrak{F}) + 2\sqrt{(\mathfrak{D}\mathfrak{C} - \mathfrak{A}\mathfrak{F})^2 - \mathfrak{B}\mathfrak{E}(\mathfrak{D}\mathfrak{C} + \mathfrak{A}\mathfrak{F}) + \mathfrak{D}\mathfrak{F}\mathfrak{B}^2 + \mathfrak{A}\mathfrak{C}\mathfrak{E}^2}}{\mathfrak{E}^2 - 4\mathfrak{D}\mathfrak{F}}. \tag{16}$$

For large values of R, Eq. 16 can be put into a somewhat simpler form. If terms of order $1/R^2$ are retained, but no higher powers, Eq. 16 can be reduced to

$$\lambda = \frac{\dfrac{\pi^6}{60}\left[\dfrac{\pi^2}{112}(1-k)^2 + \dfrac{1}{R^2}\right] - 16\nu\left(1-\dfrac{3}{\pi}\right)^2\left[\nu(1-k)^2 + \dfrac{2}{R^2}\right]}{\dfrac{4\pi^2(1-k)^3}{15}\left[1-k\left(1-\dfrac{2}{m}\right)\right]\left[\dfrac{\pi^2}{112}(1-k)^2 + \dfrac{1}{15R^2}\right] - \dfrac{8192}{\pi^4R^2}(1-k)^4\nu\left(1-\dfrac{3}{\pi}\right)^2}. \tag{17}$$

Two sets of numerical cases have been carried out. In both instances $\nu = 0.25$. Figure 2 represents the case $R = 1$, a square plate,

for which Eq. 16 has been used. Three mass ratios $m = \frac{1}{3}, \frac{1}{2}$, and 2 have been considered. The case $R = 10$ is shown in Fig. 3. The approximate formula (17) has been used here and the cases $m = \frac{1}{3}$ and

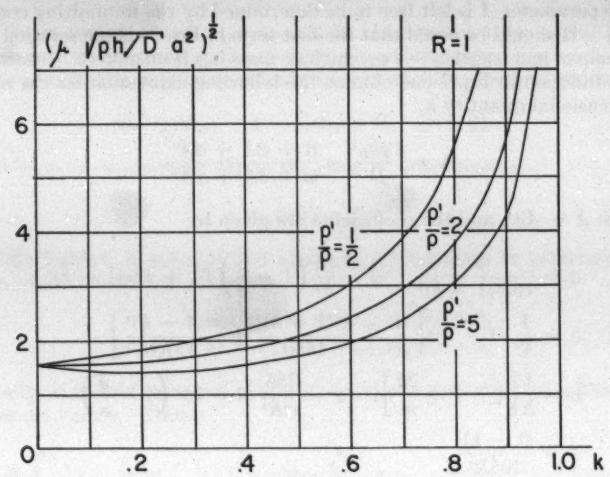


FIG. 2.

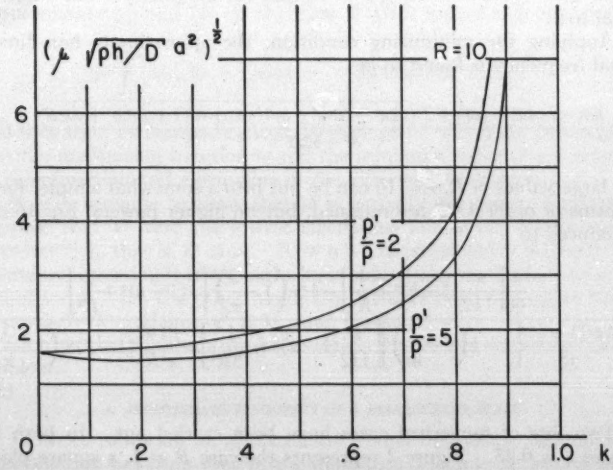


FIG. 3.

$m = \frac{1}{2}$ are shown. In both cases, $R = 1$ and $R = 10$, it should be noted that the frequency always increases for $m = \frac{1}{2}$ or higher values. On the other hand, there is a decrease in frequency of $m = \frac{1}{8}$ for part of the range in k. Cross-over then occurs with the frequency being equal to that of the unloaded plate; and, thereafter, as k increases the frequency increases as well.

5. REDUCTION TO THE CASE OF A SIMPLY-SUPPORTED BEAM

The trial function used in Section 4 has been selected in such a way that only the first term in the integrand in the numerator of Eq. 7 survives if the width b of the plate tends to zero. An upper bound to the frequency of a simply supported beam with added central mass is then found by inserting the trial function in Eq. 7, carrying out the integrations, setting $\nu = 0$, and letting b tend to 0. As in the example of the plate, $t = h$.

If μ_a^2 denotes the upper bound to the eigenvalue thus computed, it is found that

$$\mu^2 \leqq \mu_a^2 = \frac{EI \int_0^{a-l} \left[-\frac{\pi^2}{4(a-l)^2} \sin \frac{\pi x}{2(a-l)} \right]^2 dx}{\rho h \int_0^{a-l} \sin^2 \frac{\pi x}{2(a-l)}\, dx + l\rho' h}.$$

Integration then yields

$$\mu_a = \frac{\pi^2}{4(a-l)^2} \sqrt{\frac{EI}{\rho h}} \Big/ \left(1 + \frac{2\rho' l}{\rho(a-l)}\right)^{\frac{1}{2}}.$$

It should be noted that the approximate frequency μ_a thus found is the frequency of a beam of half length $a - l$ divided by a factor which is the square root of 1 plus twice the ratio of the added mass to the beam mass.

In order to compare this result with the exact solution found by Cohen and Handelman (2),

$$\left(\mu_a \sqrt{\frac{\rho h}{EI}}\, a\right)^{\frac{1}{2}} = \frac{\pi}{2(1-k)} \left[\frac{1}{\left(1 + \frac{2k\rho'}{(1-k)\rho}\right)^{\frac{1}{2}}} \right]^{\frac{1}{2}}$$

has been plotted as a function of $k = l/a$ for the parameter ratios $\frac{\rho'}{\rho} = 0$, $\frac{\rho'}{\rho} = 2$, and $\frac{\rho'}{\rho} = 6$. It should be noted that the exact and approximate solutions coincide for $\frac{\rho'}{\rho} = 0$. The solid curves in Fig. 4 represent the exact solution, whereas the circles represent the approxi-

mate values. The agreement is seen to be extremely good, although it is still open to question as to whether the comparison in the case of the plate would be nearly as favorable.

6. CONCLUSIONS

An inspection of Figs. 2, 3 and 4 shows that the effect of added mass on the transverse vibration of the rectangular plate under the edge and loading condition considered is entirely similar to that of the beam under analogous conditions. The frequency of vibration is raised above the unloaded case for a significant range of variables. It would seem from this that the attachment of mass in the manner prescribed here should

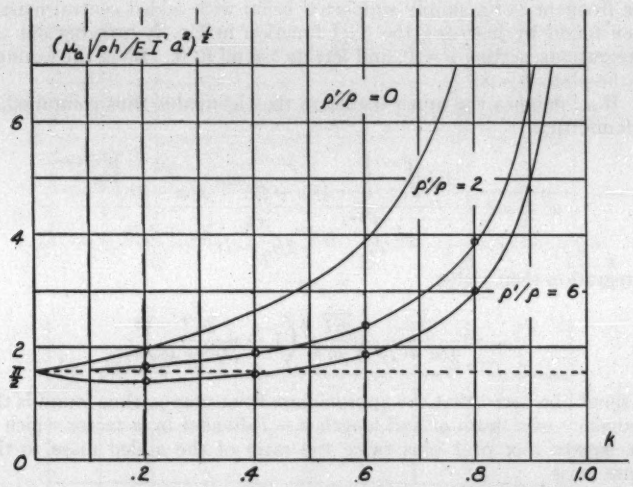


FIG. 4.

be thought of as a stiffening effect (and therefore as, in general, raising the frequency) rather than a mass loading effect. A simple computation will show, however, that for either $m = 2$ or $m = \frac{1}{2}$ there is a change of frequency (μ) of about twelve per cent at $k = 0.1$, $R = 1$, upward in the former case, downward in the latter. Since the density of the added mass is likely to be of the order of five times that of the plate, this may well be a significant figure. This result does not seem to depend on R strongly for $R \geq 1$. It will be observed that for m less than approximately one half the frequency decreases before it increases. For $m = \frac{1}{2}$, $R = 1$, the frequency is below that of the unloaded plate for $0 < k < 0.4$.

The foregoing observations seem to indicate again a conclusion found in the studies made on the membrane and beam with added mass. In order to predict the change in vibration characteristics with added mass, it is necessary to know the distribution of the mass and the relationship between the density of the added mass and that of the plate. For concentrated loads (k small) of small density, the plate is stiffened and the frequency increases. For loads of large density the frequency will also increase but not until the load is distributed across a large portion of the plate.

It should be recognized that the assumption of rigidification caused by the mass addition as assumed in this study is rather extreme. It would be interesting to consider the effect of a flexible added mass. A study is also under way at present to determine whether the results found thus far for the circular membrane, the beam and the rectangular plate extend to the case of the circular plate.

REFERENCES

(1) E. T. KORNHAUSER AND D. MINTZER, "On the Vibration of Mass-Loaded Membranes," *Jour. Acous. Soc. Amer.*, Vol. 25, pp. 903–906 (1953).
(2) HIRSH COHEN AND GEORGE HANDELMAN, "Some Effects of the Distribution of Added Mass to Vibrating Beams," *Jour. Acous. Soc. Am.*, Vol. 27, p. 177 (1955).
(3) S. TIMOSHENKO, "Vibration Problems in Engineering," Second edition, New York, Van Nostrand, 1937, p. 421.
(4) S. TIMOSHENKO, "Theory of Plates and Shells," New York, McGraw-Hill, 1940, p. 90.

Robot Hand Pipettes Radioactive Liquids.—A simple, safe, remote pipette control device that adds a two-foot extension to your lips as well as to your hands, is announced by The Atomic Center, Inc., New York City.

Designed for use in laboratories and hospitals where radioactive solutions are handled, the Model RP-1 Radi-Pipetter enables the laboratory technician to perform all pipetting operations on "hot" and "semi-hot" liquids without the necessity of handling the pipette at any stage of its use.

In addition to grasping and releasing the narrow glass tube, the Radi-Pipetter "sucks up" the solution into the pipette by means of a syringe located in the device handle and operated manually.

The Model RP-1 will accommodate practically any type or size pipette, and features replaceable parts where contamination may occur. In addition to its basic use in applications involving radioactivity, the Radi-Pipetter can also be used for the remote manipulation of other dangerous liquids such as germ cultures, acids, or volatile and toxic substances where contact or inhalation may be harmful.

Heart Surgery.—The newest techniques of heart surgery make use of circulation outside the body and give the surgeon one-half hour to work on a bloodless heart. Dr. William P. Young of the University of Wisconsin Medical School told doctors attending a postgraduate course on heart diseases of the new technique. The technique is this:

Arterial blood is pumped from a bottled blood reservoir into the large subclavian artery. The blood circulates normally through the body, but before it enters the heart through the large vein called the vena cava, it is shunted out of the body to a bottled venous reservoir. Arterial blood is supplied constantly, and venous blood removed from the body without passing through the heart.

All body tissues receive a blood supply, but the heart itself is bloodless, permitting surgery.

"Airborne" Crane.—An "airborne" crane, capable of lifting more than its own weight, has been developed by the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Va., and the Wayne Shovel and Crane Division of the American Steel Dredge Company, Fort Wayne, Indiana, now American Steel Dredge Division of American Hoist and Derrick Co.

The unit, which weighs 14,700 lb., is designed to lift nine tons at a 10-ft. radius with outriggers. Without outriggers, it has a capacity of seven tons at the same radius. The machine is also equipped with shovel, dragline, and clam-shell earth moving attachments of half-cubic yard size.

A 40-hp. gasoline engine, which utilizes standardized high mortality parts produced through an extensive engine standardization program at the Engineer Laboratories, powers the unit.

Twenty-two feet six inches long, eight feet two inches wide and six feet nine inches high, it is within the critical transport limitations imposed by cargo aircraft.

Construction equipment is considered airborne only if transportable as a unit and capable of operations within an hour after delivery. The crane, which will undergo engineering tests, is expected to be air-droppable as well as air-transportable.

In airborne tests conducted to date, tractors, scrapers, saws and a motor grader have been successfully dropped.

EFFECTS OF ELECTROLYSIS IN THE THORIUM OXIDE EMITTER *

BY

DANIEL L. GOLDWATER [1]

ABSTRACT

The conduction of electricity through thorium oxide by ions, and the plating out of thorium metal in this process, has been observed by Danforth. It is deduced by Danforth and Bodine in a previous paper (1) [2] that possibly 99 per cent of the current at 1300° C. is carried by ions. The role which this electrolysis plays in the operation and life of the thoria cathode is here considered.

On first glance, it appears that the high ionic fraction should lead to very rapid destruction of a thoria cathode. In actuality, the thorium produced by electrolysis bypasses most of the subsequent current around the oxide, so that the fraction of the total current which is effective in electrolysis is greatly reduced. A picture of the thorium oxide emitter is evolved in which the evaporation of thorium from a thin surface film is in equilibrium with the production of thorium by electrolysis of the oxide. The emitting properties are then presumably characteristic of the film; the similarity of work function of "thoria" cathodes and thoriated tungsten cathodes is cited.

The change of conductivity of sintered thoria specimens due to electrolysis has been measured. The behavior is quantitatively consistent with the above views, and with the view that the ionic fraction in the practical case increases with current. End effects in a specimen which was highly metallized by electrolysis are interpreted in terms of liberation of oxygen by electrolysis above a critical current density.

I. INTRODUCTION

Thorium oxide has been used for some time in certain specialized vacuum tube applications (2). In high powered magnetrons, "cermet" mixtures of thorium oxide and molybdenum powder are often used. These are sometimes heated directly by the passage of current. Thoria-coated and thoria "dispenser" cathodes have also been tried in magnetron applications. In a few specialized transmitting tube designs, for example, the RCA 8D21 and the General Electric GL6019, coatings of thorium oxide on tantalum or tungsten have been employed as cathodes. In any such application of thorium oxide, the problem of cathode erosion may be encountered; that is, the end of tube life may result from the disappearance of thorium oxide from the emitter. Usually the disappearance results in decrease of electron emission below the useful level. In the case of directly heated cermets, the disintegration of the oxide sometimes results in mechanical failure. One can imagine several possible causes of disappearance of thorium: sputtering, evaporation (3), reaction with the base metal (3), and electrolysis. We have determined that electrolytic disintegration is often the limiting factor in thoria cathode life under conditions where short life has been a problem.

* This work was in large part supported by the U. S. Navy, Bureau of Ships, under Contracts NObs 34141 and NObsr 52592.

[1] Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

In discussing the problem of electrolysis with relationship to the behavior of thoria cathodes, this paper will draw on several sources of information:

(*a*) Studies performed here on large crystals of thorium oxide which are reported in the Danforth and Bodine paper (1) and in a previous publication (4),
(*b*) Life data obtained in laboratory and commercial tubes using cathodes containing thorium oxide,
(*c*) Previously unreported observations of the electrolysis of sintered thorium oxide specimens.

FIG. 1. Thorium oxide crystal in vacuum furnace during electrolysis. The furnace element has been temporarily cooled. Light is provided by an incandescent filament behind the crystal.

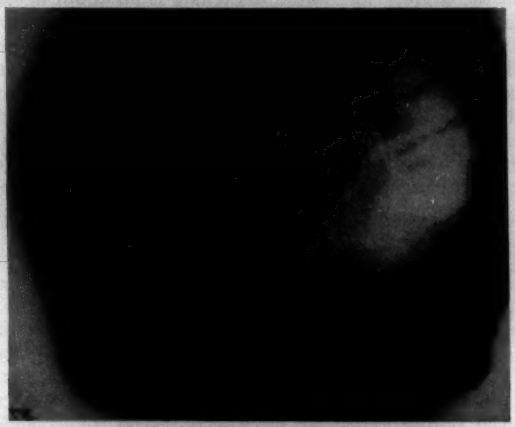
II. EXPERIMENTS ON LARGE THORIUM OXIDE CRYSTALS

Danforth and Bodine (1) describe experiments demonstrating certain polarization phenomena which occur when a current is passed through a single crystal of thorium oxide. Two observations made during the course of these experiments are of importance to the practical problem:

(*a*) The inference of a "decomposition potential" and its interpretation as the level above which continuous plating out of thorium metal from the oxide occurs,
(*b*) The estimate of 99 per cent ionic conductivity in thorium oxide crystals.

The electrolytic deposition of thorium from the oxide has been reported by this laboratory in a previously published paper (4). A brief summary of this work is pertinent here. In the experiment, a thorium oxide crystal was heated in a vacuum furnace and a current of about 100 milliamperes per square centimeter was passed through it. A darken-

ing was observed to form in the interior of the crystal starting at the negative electrode. The behavior of this darkening with respect to the electric field was what would be expected of a cloud of ions moving through the crystal lattice with a rather low mobility. In Fig. 1 is shown a crystal in which the cloud has been allowed to pass half-way across. Following the appearance of the cloud, metal is seen to deposit on the surface above the darkened portion of the crystal. In sufficient



(*a*) Clear thoria crystal. The parallel lines are pencil marks on the underlying paper to demonstrate clarity.

(*b*) Similar crystal after electrolysis, showing metal deposited on the outside.

FIG. 2.

time the darkening and the metal coating proceed across the entire crystal. At this point, electrical measurements indicate that the external metallic conduction path effectively short-circuits the crystal. Figure 2 shows a crystal specimen which has been completely covered by electrolytically deposited metal. While this experiment did not give complete information as to the detailed mechanism of the process, it gave definite evidence of the production of metallic thorium by electrolysis of the oxide. The initial darkening is no doubt due to a high concentration of excess thorium, probably in the form of ions, which is built up starting at the negative electrode under the influence of the field. The observed deposition on the surface is to be expected when the concentration of excess thorium in the interior becomes sufficiently great.[3]

TABLE I.—*Disappearance of Thoria by Electrolysis during Cathode Life.*

Type of Cathode	Current Level, amps/cm²	Disappearance Rate, g/amp-hr	Effective Ionic Fraction
Sintered Thoria Cathodes (several tubes)	0.1–0.2	10^{-3}	4×10^{-4}
Coated Wire Filament (one tube)	0.05	10^{-5}	4×10^{-6}
Coated Ribbon Filament (four tubes)	1–3	5×10^{-5}	2×10^{-5}
Coated Wire Filaments (four tubes)	1.7	2×10^{-5}	10^{-5}
Commercial Tetrode * (typical value)	ca 1.0	7×10^{-5}	3×10^{-5}

* Reported for use in service with peak of a.c. as high as 2 amps/cm².

III. ELECTROLYSIS AND THE LIFE AND OPERATION OF THORIA CATHODES

The high estimate for the fraction of current carried by ions in thorium oxide, as given in (1), should lead one to believe that the material should disappear very rapidly by electrolytic erosion. This would indeed be true if all the current passing through a thoria cathode during its life were carried by destructive ions. For instance, one would expect a coating of 20 milligrams per square centimeter passing the very modest current density of 0.1 ampere per square centimeter to be completely decomposed by electrolysis in 5 minutes.[4] Data given in Table I for several laboratory and one commercial type tube show that

[3] For the sake of completeness, it should be pointed out that it is possible to conceive of ions carrying current without being deposited out at the electrode, in the following manner: Positive ions, upon reaching the negative electrode, may gain electrons and then diffuse back through the crystal in atomic form. Consideration of the relative radii of the ions of thorium and oxygen, and the thorium atom, in connection with the thorium oxide crystal structure, makes this process seem unlikely, unless the atoms diffuse along flaws in the crystal.

[4] In this paper, all calculations of this sort are based on the assumption of a quadruply charged thorium ion.

the rate of disappearance is very much slower than that predicted above. In this table an "effective" ionic fraction is given. It is seen that the effective ionic fraction in actual cathodes is many orders of magnitude smaller than unity.

The discrepancy between the large value of ionic fraction obtained in the basic experiment and the much smaller effective value obtained on the basis of electrolytic destruction of operating cathodes is only superficially paradoxical. The higher figure is based on polarization measurements and measurements involving the electrolytic product when only a small charge is passed through the crystal. If charge is passed continuously over a long period of time, the metal produced in the early part of the process bypasses most of the subsequent current around the semiconductor so that most of the measured charge is actually transported by a metallic, rather than an ionic mechanism.

These considerations have led us to form a tentative picture of the role of electrolysis in the operating thoria cathode. In practice the thorium oxide in a cathode consists of a fine powder, and we assume that each particle acts in the manner we have observed with single crystals. When current is passed through such a cathode, some or all of the crystallites may experience a voltage greater than the decomposition potential and start to decompose. However, as observed above, the metallic thorium which is released should coat each crystal, substantially bypassing most of the current around it. Since the rate of evaporation of metallic thorium is high compared to that of thorium oxide, it is expected that the life of a cathode is then determined by the equilibrium which should be set up between the evaporation of this metallic layer and its replenishment by electrolysis.

We are further led to believe that the emitting properties of "thoria" cathodes cannot be considered to be the emitting properties of thorium oxide. (In fact it appears doubtful that the emitting properties of thorium oxide have ever actually been measured.) Rather the emitting surface must be regarded as a thin film of metallic thorium or possibly a complex thorium-oxygen layer dispersed over the surfaces of the material.[6] In this connection, it is interesting to note that the measured Richardson work functions for "thoria" cathodes (2.55 ev) and for thoriated tungsten cathodes (2.65 ev) are very similar.

Visual observation of sintered thoria laboratory cathodes which have been deeply eroded by electrolysis has yielded some corroboration of the above assumptions. It has been observed that while such cathodes when new are quite white, they quickly become dark gray when current is passed through them, and remain gray during life. More

[6] H. Y. Fan (5), working with a thoria-tungsten "Cermet" cathode, deduced the presence of a thin layer of adsorbed thorium on the emitting surface. He explained the production of free thorium by a reduction reaction between the tungsten and the oxide. Our view, based on work done subsequent to Fan's publication, is that at temperatures up to 2250° K. the dominating factor in the production of free thorium is electrolysis.

striking is the microscopic appearance of such cathodes after life. Small metallic globules can be seen embedded in the sintered ceramic. Both of the above observations are taken as evidence of the liberation of metallic thorium by electrolysis of the oxides.

IV. EXPERIMENTS WITH SINTERED THORIA SPECIMENS

We have reinforced some of the assumptions concerning the mechanism of electrolysis in operating cathodes by studying the behavior of sintered cylinders of thorium oxide. These aggregates of small particles more nearly approximate an actual cathode. In the first experiment of this sort, we simply followed the resistance of a specimen as current was passed through it in a vacuum furnace. Figure 3 shows

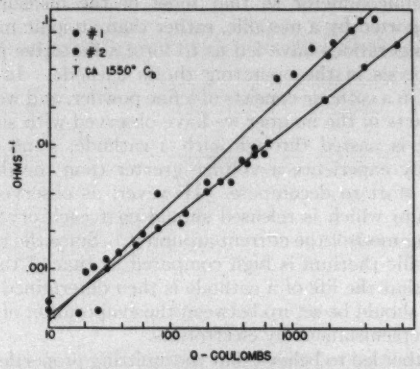


FIG. 3. Change of resistance of two sintered thoria specimens by passage of charge.

this resistance as a function of charge over many orders of magnitude. In the initial low conductivity state, the specimen exhibited the expected semiconductor behavior. As the electrolysis progressed, noticeable room temperature conductivity developed, and finally the conductivity appeared to be predominately metallic in that the room temperature conductivity was high and the temperature coefficient of conductivity was negative and small. This behavior is interpreted in terms of electrolytic deposition of metallic thorium over the surfaces of particles in the sintered mass. When the high conductivity state was reached, the limit of increase of current was heating of the specimens by I^2R losses. At the end of a run, the current density might be over 10 amps/cm^2.

A very simplified mathematical description of the change of conductivity during this process will perhaps clarify the verbal description. The following assumptions are made.

(*a*) The conductivity of a sintered specimen undergoing electrolysis may be represented by a semiconductor conductivity σ_1 and a metallic conductivity σ_2 in parallel. Consideration of the equivalent circuit for this situation leads to the following equations:

$$\sigma_{(\text{total})} = \sigma_1 + \sigma_2 \tag{1}$$

$$\sigma_2 = \sigma_1 \left(\frac{I}{i_1} - 1 \right). \tag{2}$$

In the above equations, I is the total constant current passing through the specimen.

(*b*) A fraction of the current through the semiconductor is carried by thorium ions which are deposited out and add to the metallic conductivity. Since this ionic fraction may be current dependent, we write in general for the time change of metallic conductivity

$$\frac{d\sigma_2}{dt} = f(i_1) i_1. \tag{3}$$

From Eqs. 2 and 3 above we can obtain:

$$\frac{d\sigma_2}{dt} = f(i_1) i_1 = -\frac{\sigma_1 I}{i_1^2} \frac{di_1}{dt} \tag{4}$$

$$\frac{t}{\sigma_1 I} = -\int \frac{1}{f(i_1) i_1^2} di_1 + c. \tag{5}$$

(*c*) In order to arrive at a simple solution, it is necessary to assume that σ_1 does not change.

(*d*) An assumption must be made as to the nature of $f(i_1)$. The simplest possible assumption is that the ionic fraction is independent of current, then $f(i_1) = F$ and the following solution is obtained, remembering that tI is the total charge, Q, passed through the specimen.

$$\sigma_{(\text{total})} = \sqrt{2FQ\sigma_1 + \sigma_0^2}. \tag{6}$$

If, however, we take the simplest form of current dependence of the effective ionic fraction that is $f(i_1) = Gi$, the conductivity as a function of charge then becomes

$$\sigma = \sqrt[3]{3GQI\sigma_1^2 + \sigma_0^3}. \tag{7}$$

The qualitative difference between the two assumptions with respect to $f(i_1)$ is this: In the first case, we have assumed that the fraction of current carried by a semiconductor mechanism which is effective in

electrolysis is independent of the current level. In the second case, it is assumed that the effective ionic fraction increases with current. It seems most likely that the latter condition is true.[6] When the second

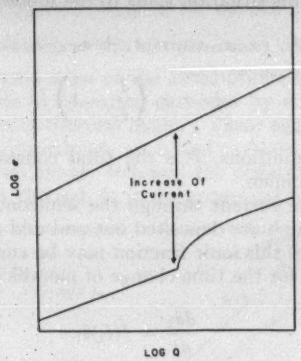


FIG. 4. Predicted effect of sudden increase of current on the charge-conductivity relationship. The lower curve is for the case where the ionic fraction increases linearly with current density. The relative magnitude of the two curves is of no significance.

assumption is used, the relationship between charge and conductivity contains current as a parameter. Figure 4 shows how, on the basis of this formulation, we should expect the conductivity to behave when

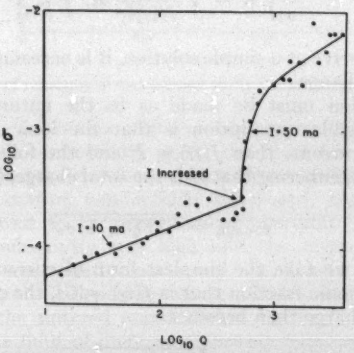


FIG. 5. Effect of sudden increase of current in a sintered thoria cylinder on the charge-conductivity curve. Note the similarity to the lower curve of Fig. 4.

[6] One reason for this belief lies in the distribution of particle sizes encountered in a sintered specimen. At a given current level, some of the particles may be above the decomposition potential, and others below it. As the current is raised, more particles should experience a voltage drop which equals or exceeds the decomposition potential.

the current is suddenly increased. In the lower curve, the form $f(i_1) = Gi_1$ which was assumed for the effective ionic fraction gives rise to the shift in the charge-conductivity relationship when the current is suddenly changed. It must be pointed out that this particular functional form is not unique in this respect; any monotonic increasing function will produce the same type of behavior. For the purpose of this analysis, which has only qualitative validity, it was convenient to assume a linear dependence. Figure 5 gives the experimental data showing the effect of a sudden change of current on the development of metallic conductivity by electrolysis. Comparison with the predicted behavior of Fig. 4 shows a strong similarity to the lower curve. Thus we have qualitative verification of the current dependence of the effective ionic fraction.

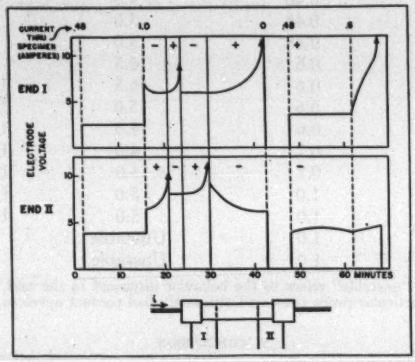


FIG. 6. End-effects produced by passage of current through a metallized thorium oxide specimen. The arrows indicate unstable contact voltage which always occurred at the positive end, as described in the text.

The conductivity of specimens which have been heavily electrolyzed was high enough so that they could be heated by I^2R losses with currents of a few amperes. One such specimen was mounted between two end pieces in a pumped tube with two probes placed along its length. Figure 6 shows what happened when current was passed through this specimen. The voltages plotted are those between each probe and its nearest end piece. At first a current of 0.48 amp was passed. The voltage immediately rose to a constant value. When the current was increased to 1 ampere, the voltage between the negative end and the nearest probe decreased while the voltage at the positive end increased and finally became unstable. Upon reversing the polarity, the instability at the now negative end quickly disappeared while the voltage at the now positive end increased and became unstable. This association

of instability at this current level with the positive end piece reproduced itself with each reversal of polarity. We explain this behavior in the following manner: oxygen ions migrate to the positive end piece and there cause bad contact, probably by reacting with the molybdenum of the end piece. By repeating this procedure at various current levels, we established that the instability only evidenced itself above a certain current level. The critical value for the specimen examined was 0.6 amp (3 amps/cm²). The data are tabulated in Table II.

TABLE II.

Positive End	Current	Probe Voltages	
		Right End	Left End
Left	0.4	4.0	4.0
Left	0.46	4.0	4.0
Left	0.48	3.0	3.5
Right	0.48	3.0	4.0
Right	0.6	4.5	5.0
Left	0.6	4.5	Unstable *
Left	0.6	5.0	Unstable
Left	0.6	4.0	Unstable
Left	0.7	4.0	Unstable
Left	0.7	5.0	Unstable
Left	1.0	5.0	Unstable
Left	1.0	5.0	Unstable
Right	1.0	Unstable	5.0
Right	1.0	Unstable	5.0

* The notation "unstable" refers to the behavior discussed in the text, in which voltage measured at the particular probe rises, and ultimately bad contact develops.

V. CONCLUSION

The electrolytic decomposition of thorium oxide has been established. The electrical behavior of sintered thorium oxide specimens passing high current density is in large measure due to the products of electrolysis. General considerations lead us to believe that the conductivity of such specimens should increase with charge according to a power law with the power less than one. It is felt that the "effective ionic fraction" which enters into this power law as a parameter should increase with current, giving rise to a shift in position of the conductivity-charge curve when current is suddenly increased. Both of these expectations are qualitatively verified by experiment.

Unstable resistance behavior at or near the positive electrode appears to be related to a critical current density or a very sharply rising function of current. This is interpreted in terms of the deleterious effect of electrolytic oxygen released at the positive end.

The above observations are extended to a tentative picture of the role of electrolysis in the so-called "thoria cathode." It is proposed

that the emitting surface is covered with a thin film of electrolytically produced thorium (or possibly a complex thorium-oxygen film). The film thickness should be dependent upon the rate of electrolysis and upon the rate of evaporation. The conductivity will likewise be affected by the presence of the surface metallic film.

The rate of electrolytic decomposition undoubtedly is an important factor in the life of thoria cathodes, in those cases where high average current densities are passed.

REFERENCES

(1) W. E. DANFORTH AND J. H. BODINE, "Polarization in Thorium Oxide Crystals," JOUR. FRANKLIN INST., Vol. 260, p. 467 (1955).
(2) W. E. DANFORTH, "Advances in Electronics V," New York, Academic Press, 1953, p. 169.
(3) E. M. SHAPIRO, *J. Am. Chem. Soc.*, Vol. 74, p. 5233 (1952).
(4) W. E. DANFORTH, *Phys. Rev.*, Vol. 86, p. 416 (1952).
(5) H. Y. FAN, *J. Appl. Phys.*, Vol. 20, p. 682 (1949).

Radiation Pressure Float.—A new General Electric measurement device has enabled the fast-growing ultrasonics industry to establish needed codes and standards. The new development, known as a radiation pressure float, is the first device to be used in measuring the acoustic power output of ultrasonic generators—generators that emit powerful sound waves beyond the range of the human ear.

Donald B. Connelly of the G-E General Engineering Laboratory in Schenectady said the device to evaluate ultrasonic equipment was "much needed in a field that is becoming extremely crowded."

In an address before the Utica-Rome chapter of the American Society of Metals, Connelly declared that "ultrasonic cleaning has become a big business in the present-day industrial complex."

He added:

"No longer is it a question of just two or three companies competing for the business of a few specialty manufacturers. Now a dozen firms are out to win a mass market."

The mushrooming competition, he said, created the need for establishing standards by which one piece of ultrasonic equipment may be compared to another.

During the past five years ultrasonic cleaning of small parts, such as instrument ball bearings, has become widely adopted in various industries. General Electric laboratory experts have turned ultrasonics to other uses, including the impregnation of insulation materials, bonding of metals and others.

G-E's pioneer measuring device consists of a small cone-shaped inverted funnel with hollow walls. When submerged in a liquid that is being agitated by the sound waves, the funnel rises or sinks according to the strength of the waves.

"In this way, engineers are able to take a reading very much in the manner of a service station attendant using a hydrometer to register the density of battery liquid or anti-freeze mixture in an automobile," Connelly said.

Ultrasonic cleaning calls for setting up sound waves in a body of liquid—sometimes water, sometimes an organic solvent—and the work to be cleaned is submerged in this agitated liquid. Tiny, precision parts are cleaned in a small fraction of the time that other methods would require.

Vibrating Reed Electrometer.—A new, improved Vibrating Reed Electrometer which provides wider flexibility of range in a standard instrument has been announced by the Applied Physics Corporation, Pasadena, Calif. The new Model 31, which replaces the Model 30, has standard ranges of 1, 3, 10, 30, 100, 300, 1000 mv and 3, 10, 30 volts. The Model 31 is capable of detecting a current as small as 1.0×10^{-17} amperes originating in a high impedance source. Charges as small as 5×10^{-16} and voltages as small as 0.02 mv can be detected. Radioactivity measurements, C^{14}, H^{3}, S^{35} determination, pH determination, mass spectrometry and measurement of electrical properties are a few of the applications for which this instrument can be used.

It operates by converting the d-c. input signal to a.c. through the use of mechanical energy to move the impressed charge through an electrostatic field. The a.c. signal thus produced, which is a measure of the impressed charge, is amplified in a stable a.c. amplifier and then rectified and used to drive the indicating meter. A portion of the rectified a.c. is applied as a negative feed-back to give high stability.

PROCEEDINGS OF THE 250TH ANNIVERSARY DINNER AND ANNUAL MEETING

January 18, 1956

RECEPTION AND DINNER

Approximately 275 members and guests attended the reception and dinner preceding the Annual Meeting which commemorated the 250th Anniversary of the Birth of Benjamin Franklin.

The Reverend Ernest A. Harding, Rector of Christ Church in Philadelphia, delivered the invocation, and the following Toast to Benjamin Franklin was proposed by the President, S. Wyman Rolph.

TOAST TO BENJAMIN FRANKLIN

MR. ROLPH: "Ladies and Gentlemen, will you rise so we may toast the great man in whose memory The Franklin Institute was founded.

"Benjamin Franklin once told John Baynes that if certain things were done, world peace might be achieved in one hundred and fifty to two hundred years. That was in 1783. It is amazing to note how clearly he outlined the steps toward that goal. Nearly two centuries ago, he wrote that the threat of massive retaliation by air might be the first step in preventing aggressors from starting wars. This objective, written at the time of the first balloon flight, is a policy of defense of the Free World today.

"Franklin also said that a Congress of Nations should be formed, as we now have in the United Nations.

"But, he added, more than this would be needed to bring enduring peace. He thought that free and voluntary communication must exist among the peoples of all countries—the private citizens themselves, not just their governments. Over much of the world today, we have this free and voluntary communication among private citizens.

"Tonight we honor the memory of a great man on the 250th anniversary of his birth. Thomas Campbell once said, 'To live in hearts we leave behind is not to die.' Franklin lives in our hearts today. May God grant that he continue to live in the hearts of future generations."

* * *

GREETINGS AND ANNUAL MEETING

MR. ROLPH: "Distinguished guests, members of The Franklin Institute, Ladies and Gentlemen: This third Wednesday of January, 1956, not only falls within the week of world-wide observance of

Franklin's birth, but also marks the Annual Meeting of The Franklin Institute.

"I would like to identify a few of our distinguished guests at the head table. And in order that our distinguished guests in the audience can get a good look at you, will you please rise?"

His Excellency, the Ambassador of Sweden, Mr. Erik Boheman.
Mr. William Francis Gibbs, Franklin Medalist of 1953.

"The following members of the Governor's Benjamin Franklin Sesqui-Bicentennial Commission of Pennsylvania:"

The Honorable Mary Varallo, State Representative
The Honorable Charles C. Smith, State Representative
Dr. William Lingelbach, American Philosophical Society

"And I might point out that Mr. C. L. Jordan and I are both members of the Commission and so are sitting at the head table in a dual capacity.

"Past Presidents of The Franklin Institute:"

Mr. Charles S. Redding
Mr. Richard T. Nalle

"And the Chairman of our noted Committee on Science and the Arts:"

Mr. Ralph McClarren.

"The others seated at the head table you will meet as our program progresses.

"Because the January issue of our JOURNAL was devoted to papers on the 'Panorama of Progress' in honor of Benjamin Franklin, Minutes of our December Stated Meeting will not be published until the February issue. We therefore have no Minutes to submit for your approval tonight! If you have not seen this special commemorative issue, I advise you to waste no time: We're proud of it; and, I think, justly so.

"Another commemorative act may be seen here tonight—these new cases that contain an illustrated biography of Franklin. The four cases relate to 'Franklin the Printer and Journalist,' 'Franklin the Citizen,' 'Franklin the Scientist and Inventor,' 'Franklin the Statesman.'

"According to our By-Laws, eight Managers are elected annually by mail ballot to serve for a three-year term. Will Dr. George S. Crampton give us the Tellers' report?"

Dr. Crampton reported that the following had been elected Managers:

A. Felix du Pont, Jr.	Lionel F. Levy
J. G. R. Heckscher	Charles Penrose
Clarence L. Jordan	R. G. Rincliffe
Ralph Kelly	Philip H. Ward, Jr.

MR. ROLPH: "I declare these eight members duly elected Managers of The Franklin Institute for a term of three years. And may I thank Dr. George Crampton, Dr. Joseph Hepburn, and Mr. Howard Stoertz for their services as Tellers.

"At this afternoon's meeting of our Board of Managers, Mr. James McGowan, Jr., was elected to fill a vacancy on the Board created by the resignation of Dr. Hiram Lukens, who has moved away from the City. So we welcome Mr. McGowan as a brand new member of our Board of Managers.

"The Annual Report of the Board of Managers will be presented at a Stated Meeting in the spring after receipt of our auditor's report.

"I now call upon Dr. Henry B. Allen for the Secretary's report. Dr. Allen."

DR. ALLEN: "Elections to membership, recorded during December, resulted in a net gain in the following classes of membership:

Associate	7
Student	33
Individuals with Library privileges under Company membership	5

Our total membership at the end of 1955 was 7094."

MR. ROLPH: "Thank you, Dr. Allen. Ladies and Gentlemen, when Dr. Allen came to the Institute in October 1935 as its top executive staff officer, we had approximately 2500 members. Now we have *almost* tripled that figure. During two decades of service, Dr. Allen has given freely of himself—of his time, his energy, and, during our lean years in the 'thirties, even of his money. His warmth and feeling for others is so great it has penetrated even his natural New England reserve! And he has endeared himself to many. Tonight's was his last report at a Stated Meeting, for next Wednesday he retires. Ladies and Gentlemen, may we have a rising vote of thanks that will also be an expression of our good wishes for many happy years of good health and leisure."

AWARDS

Presentation of the Franklin Commemorative Medal to The Franklin Institute

MR. ROLPH: " 'No man is ever completely and permanently a stranger to his fellow man. Man belongs to man. . . . A reverence for life does not allow the scholar to live for his science along. . . . It

does not permit the artist to exist only for his art. . . . It refuses to let the business man imagine that he fulfills all legitimate demands in the course of his business activities. . . . It demands from all that they should sacrifice a portion of their own lives for others.'

"Those words were written about Albert Schweitzer. But how well they may be applied to Benjamin Franklin! I do not intend to recite his accomplishments, the great good that he bestowed upon others. Nor do I think it necessary to go into detail about the humanness of the man. We, his heirs, know these things.

"Yesterday marked the 250th anniversary of his birth. The very fact that it is being observed and commemorated throughout the world, throughout the year—in many lands, in many tongues—attests to the greatness and magnitude of his personality, his thinking, his deeds.'

"The Franklin Institute has been attempting to honor Franklin's name for 132 years. This year, we join with millions of others in that dedication. One of these millions is with us tonight. I call upon Mr. C. L. Jordan, member of the Board of Managers of The Franklin Institute, and Chairman of the 250th Anniversary Committee for the International Celebration of the Birth of Benjamin Franklin. Mr. Jordan."

MR. JORDAN: "It is a very special privilege for me to speak to you tonight—not only as a fellow-member of The Franklin Institute, but also as a member of The Committee authorized by Congress to bring you a message of very deep appreciation from the Government of the United States.

"When your Board of Managers determined to honor the memory of Benjamin Franklin on his 250th Anniversary, we first thought of only a small celebration, limited to an exchange of ideas among the Societies and Institutions of which he was a member—or which he founded or helped.

"But such is the stature of the man, that our original and limited plans soon developed into a great outpouring of cooperation in 51 countries of the world. Franklin's spirit was never more alive and vital than it proved to be in this year, two and a half centuries after he was born.

"Hundreds of organizations, with hundreds of thousands of members, seized upon this opportunity to do what Benjamin Franklin believed was necessary to help bring an enduring peace to the world. They will cooperate, all during the year of 1956, in a free and voluntary communication of ideas to help improve international understanding.

"Most of you already have seen the magnificent Anniversary issue of the JOURNAL OF THE FRANKLIN INSTITUTE. That contains just a few examples of the many papers, articles and broadcasts that are now scheduled to reach nearly half a billion people in these 51 countries during 1956.

"The Celebration, we believe, will be the largest, voluntary international forum in history; and it is correctly dedicated to the man who said this kind of thing must be done if the peoples of the world were to learn to understand each other and achieve mankind's greatest objective—a durable peace.

"I should like to quote to you what the Honorable Leo W. O'Brien of the Congress of the United States, said of this Celebration in the Congressional Record of June 22nd, 1955:"

> I want to congratulate especially The Franklin Institute, which is preparing this Celebration. Perhaps the world-wide dissemination of what Franklin taught may help turn back, even at this late date, the dark, creeping tides of Communism.

"That was a heavy responsibility to place upon the plan for the celebration, but I think you might be interested in just some examples of how it is working.

"Most of you have seen our Anniversary issue of the JOURNAL. Similar issues are being published in many countries. We have just received one from Peru with 14 papers on Benjamin Franklin. Another, *Nuevo Mundo*, published in the Argentine and circulated throughout South America, is entirely devoted to Franklin. The magazine *France* is doing the same, and papers and programs are arriving daily from India, Thailand, Iran, Japan, Ecuador and all of the countries in Europe. The *Autobiography* is now being translated and issued in Persian and Japanese in addition to its earlier languages.

"The important part about all of this is that it is all voluntary—all done by local people who love and believe in the ideals and principles of Benjamin Franklin.

"Some of you may ask why did The Franklin Institute, whose major work is in science, promote a program of free communications on such a broad basis. The answer is very clear.

"Benjamin Franklin himself believed that the free communication of ideas was man's greatest service to man. He considered the learned Societies, Scientific Institutions and a Free Press as necessary for this purpose, and much of his life and achievements were shaped by this belief.

"He was an intensely practical man. The experimental method developed by the scientific societies of the 17th and 18th Centuries appealed to him tremendously. He was incredibly curious, and through his communications with these groups, he was able to share in the thoughts and experiments in all of the great fields of the Universe.

"In time, he became a member of 28 learned societies and academies in Great Britain, France, The Netherlands, Germany, Italy, Russia, Spain and America. He studied their memoirs and transactions with eager interest. He suggested that his own American Philosophical Society, which he founded, should exchange papers, minutes and transactions with similar groups in these countries.

"Without such a broad communication of ideas, thoughts and knowledge, it would have been almost impossible for a man in Colonial America to have become as successful in so many fields of endeavor—as scientist, inventor, publisher, educator, statesman and public servant.

"The Congress of the United States thought of these things when they met to consider the most fitting tribute to Benjamin Franklin on the 250th Anniversary of his Birth. They felt, as we believe Franklin would have felt, that honor should be paid to those who make his type of success possible.

"The Franklin Commemorative Medal for Distinguished Service was designed for this purpose. On it you will note words taken from Franklin himself: 'Wise and Good Men are the Strength of a State.' The complete quotation adds the words 'far more than Riches or Arms.'

"Some day, the world will come to recognize the truth of that statement. The position of a country in the Council of Nations will be determined, not alone by its material wealth or the power of its armaments, but even more by the contributions of its great men and women to the welfare and progress of all mankind.

"Benjamin Franklin believed this more than 200 years ago. He knew and said that the road would be long and difficult. But he never lost his faith in the belief that some day 'wise and good men' would be recognized as 'the strength of a State far more than riches or arms.' And that they would freely communicate and share their ideas among each other.

"The United States honors that Philosophy in the creation of The Franklin Medal. It will be awarded to the Societies, Institutions and Enterprises related to Franklin, whose members have done so much—and are doing so much—to help make it come true.

"Sir Winston Churchill, with his great gift of stating a fact clearly and powerfully, once said:"

> If the human race wishes to have a prolonged and indefinite period of material prosperity, they have only got to behave in a peaceful and helpful way toward one another, and science will do for them all they could wish and more than they could dream.

"That is the great possibility that the Scientific Institutions have bequeathed to the world. It was the possibility that Franklin saw and that your Board of Managers endorsed in the plan for this Celebration.

"So many great developments have been shared among countries that it would be impossible to mention all of them.

"We know, for example, that among the first Founding Fathers of the Electrical Science were Gilbert of England; Von Guericke of Germany; van Musschenbroek of The Netherlands; Franklin of America; Volta of Italy; and Ampère of France. Here were six men from six different countries, in an age of wars and uneasy peace—

separated by thousands of miles and more than 100 years—yet their ideas were exchanged through the Scientific Societies and Institutions and the infant industry of electricity started on its destiny as mankind's most useful servant.

"Today's magnificent development of the nuclear science, which promises to be of untold benefit to peoples everywhere, is another example of putting together the ideas and inventions of many men and women from many countries—truly an international project.

"These facts give rich meaning to the words inscribed on the Medal created for Franklin's 250th Anniversary. We hope that, following the Conference last year on the peace-time uses of atomic energy, the world will enter a new era of communicating and sharing more generously with each other the basic fruits of science . . . that all nations will follow the policies of Benjamin Franklin which we are promoting today as the central theme of this Celebration.

"Mr. Rolph, in presenting this Franklin Commemorative Medal to The Franklin Institute, I am authorized to say that the Congress of the United States is very proud to recognize the distinguished services the Institute has performed for the advancement of knowledge and understanding among the peoples of the world.

"It is an added pleasure to tell you also that this Medal was designed by Laura Gardin Fraser, whose husband, James Earle Fraser, created the magnificent statue here in this Hall. Franklin believed completely in the full equality and abilities of men and women, just as he did in all peoples. There could be no finer example of his teachings than the simple fact that two of his greatest memorials were created by husband and wife.

"It is a privilege for me to present this Medal, in the name of the Congress of the United States, in the memory of the man whose traditions you carry forward so well—Benjamin Franklin."

MR. ROLPH: "Thank you, Mr. Jordan. This is an honor I, as President of The Franklin Institute, accept in behalf of membership.

Presentation of the Franklin Medal to Professor Arne Tiselius

"The Franklin Medal is the highest award of The Franklin Institute. Founded in 1914 it is awarded annually to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance knowledge of physical science or its applications. Ordinarily, we make this award at our Medal Day Ceremonies held each October. However, we deferred making our 1955 award until tonight so that it could be part of this special Franklin observance. I now call upon Dr. N. E. Funk, Chairman of the Franklin Medal sub-committee of our Committee on Science and the Arts. Dr. Funk."

DR. FUNK: "Mr. President, I present Arne Tiselius for an award.

"Professor Tiselius was born in Stockholm in 1902. At the age of nineteen he entered the University of Uppsala where most of his researches have been carried out. In 1931, upon completion of his thesis on the electrophoresis of proteins, he was granted the degree of Doctor of Philosophy. In the following years he became a prominent member of the Physical Chemistry Institute of Professor Svedberg and in 1938 was promoted to a professorship of biochemistry in the University of Uppsala. Ten years later a chair of biochemistry was founded for him, and the next year he was chosen to direct the new Institute of Biochemistry established by the University.

"Professor Tiselius has held many responsible offices and has been the recipient of many honors, all of which testify as to his world-wide reputation in the field of biochemistry. He is an honorary member of many scientific societies, both here and abroad, and, in 1948, was awarded the Nobel Prize in Chemistry.

"Professor Tiselius' outstanding work is his development of electrophoretic and adsorption methods for the separation and analysis of proteins, enzymes, and other substances of biological importance.

"Electrophoresis is the movement, usually in a liquid medium, of large molecules, colloidal particles or microscopic particles in an electric field. The electrophoretic method of Tiselius, utilizing an apparatus bearing his name and known also as the moving-boundary method, depends upon measurements of changes in the refractive index of a colorless boundary between the substance under investigation and the solution medium. These measurements provide a means of following the movement of this boundary for each active component when an electrical potential is applied, and thus a means of separating and studying the properties of various complex biocolloids. For example, by this means certain proteins previously considered single entities have been shown to be mixtures of several substances and have been analyzed.

"The adsorption method of Tiselius provides another very useful means for the separation and analysis of proteins, amino acids, and other substances through their selective adsorption on the surface of a material such as carbon. This method likewise depends upon special apparatus developed by Professor Tiselius whose adsorption cell includes a column of an adsorbent, means for passing a solution at a controlled rate through this adsorbent, and means such as measurement of refractive index for the continuous determination of the concentration of the solution after it has passed through the zone of adsorbent.

"The results of Professor Tiselius' brilliant investigations in protein chemistry have been published in many scientific journals and have

thus been made available to and have been been used by many other investigators in this field.

"I present Arne Tiselius, of Uppsala, Sweden, as a candidate for The Franklin Medal, 'In recognition of his brilliant investigations in biochemistry, particularly, his contributions to the knowledge of the proteins, and of his development of revolutionary new techniques and a powerful tool for use in the field of protein chemistry.' "

MR. ROLPH: "Professor Tiselius, on behalf of The Franklin Institute of the State of Pennsylvania, I present to you this Franklin Medal and the Certificate and Report which accompany it. And, at our Stated Meeting in December, our membership elected you to Honorary Membership in The Franklin Institute. This, sir, is your certificate of membership. And here is your card of membership."

PROFESSOR TISELIUS: "Mr. President, Members of The Franklin Institute, Honored Guests: In awarding the Franklin Medal, you have done me a great honor for which I am truly grateful. I am also very much touched by the fact that you have chosen to give me this great distinction on the occasion of the celebration of the 250th Anniversary of the birth of one of your greatest men and a national hero, Benjamin Franklin. You have chosen to distinguish on this occasion a research worker from a small and distant country in the far north and I would like to interpret this as a symbol of the true international spirit for which Benjamin Franklin was such an active spokesman. I understand that normally on an occasion like this, I ought to give some sort of a lecture telling of my work, but on account of the special circumstances, I am relieved of this duty.

"However, I would like to say a few words about Benjamin Franklin and my own country. You will be interested to know that Benjamin Franklin played an important role in the development of friendly relations between the countries. The initiative for the first treaty of friendship and commerce between the United States and Sweden was taken by King Gustavus III. I quote John Adams who wrote in 1782: 'The King of Sweden has chosen to become the first power to offer a treaty with the United States . . . . Tell the Ambassador privately that we shall see to it that it was this sovereign who was the first to do us this honor.'

"King Gustavus III was a great admirer of the new republic. In a letter of October 18 1776, he wrote: 'If I were not what I am, I should go to America to follow at close view all the vicissitudes of this new republic.'

"The treaty was signed on April 3, 1783, in Paris for Sweden by Count Gustaf Filip Creutz and for the United States by Benjamin Franklin. The commission and instructions for Franklin were 'done in Congress at Philadelphia the 28th September 1782, signed by John Hanson, President of the United States in Congress Assembled,' and

these instructions gave to Franklin full powers to act. It may be of interest to know that John Hanson's grandparents came as colonists from Sweden to New Sweden on the Delaware in the year 1643.

"Fortunately I am not a king and I can go almost anywhere, whenever I like. Distance and time may be obstacles but I can assure you all, that I did not hesitate when deciding to try to come here on this great occasion. I have always enjoyed so much friendship and encouragement from this great country and also during this visit have been warmly welcomed everywhere. This evening and the great honor you have done me mark the height of all good will I have met in this country. On behalf of my country, my collaborators and myself, I wish to say thank you, all."

ADDRESS

MR. ROLPH: "It is now my great pleasure to welcome back to this Memorial Hall a man who is no stranger here. One who is no stranger to the name Franklin—for he is one of our country's eminent Franklin scholars, editor of ISIS, an International Review devoted to the History of Science and Its Cultural Influences, and member of the Department of the History of Science at Harvard University. I present Dr. I. Bernard Cohen. Dr. Cohen."

* * *

(Dr. Cohen's address appears on p. 289 of this issue of the JOURNAL.)

* * *

MR. ROLPH: "Thank you, Dr. Cohen. Ladies and Gentlemen, this evening will be remembered by me for many years, and, I hope, by all of you here. We have commemorated; we have honored; we have been honored. It has been a wonderful evening.

"And, Dr. Franklin [nodding to statue], we thank you.

"The meeting is adjourned."

* * *

NUCLEAR ENERGY NEWS

REVISED AEC RADIOISOTOPE REGULATION

The Atomic Energy Commission has issued a revised regulation—"Licensing of Byproduct Material"—which removes certain restrictions on the sale of radioisotopes abroad and simplifies procedures governing domestic distribution. The revised regulation was effective February 10, 1956. It replaced the existing "Radioisotopes Distribution" regulation, first issued in 1951, governing distribution and use of radioisotopes shipped to distributors and consumers from various AEC installations through the Commission's Isotopes Division in Oak Ridge, Tennessee.

A system of general and specific licenses is established by the new regulation covering distribution of byproduct radioactive materials produced in nuclear reactors. The revision brings the regulation into conformity with the Atomic Energy Act of 1954 and liberalizes export procedures as announced by Dr. Willard F. Libby of the Commission during the International Conference on Peaceful Uses of Atomic Energy in Geneva last August.

The revised regulation sets up procedures by which scientists in other countries may more easily obtain U. S. produced radioisotopes. It makes more conveniently available to them radioactive materials for use in medicine, agriculture, industry and the physical sciences. Scientists and research groups in other nations can now deal directly with production and distribution centers in this country.

Except for export to Soviet-bloc countries, Commission licensees in the U. S. will now be able to ship byproduct materials having an atomic number from 3 to 83, inclusive, directly to persons abroad. The Commission will keep itself informed as to the kind, quantity, and destination of exports by having U. S. licensees report to the Commission within 90 days after an export, showing the kind and quantity of isotopes exported, the consignee's name and address and the date of export.

In the United States the revised regulation will help American researchers and the growing body of radioisotope users by raising the limit on quantities of radioactive materials available to each user under general license. These increased quantities, while far below those which could cause any danger to the general population, are nevertheless of importance to research and to practical applications of radioisotopes in science and industry. The revised regulation lists 65 byproduct materials which may, within specified levels of radioactivity,

be possessed under general license, provided that no person shall at any one time possess more than 10 scheduled quantities.

Marketing of a more effective static eliminator containing polonium-210 is aided. Such eliminators must be manufactured in accordance with Commission-approved specifications contained in the manufacturer's license. A similar provision in the old regulation was confined to eliminators containing not more than 125 microcuries of polonium-210. Under the revised regulation licensed manufacturers may distribute to persons not having specific licenses static eliminators containing up to 500 microcuries of polonium-210.

The revised regulation provides a new category of sealed sources—spark gap and electronic tubes containing not more than 5 microcuries of cesium-137 or nickel-63 per tube, or not more than 1 microcurie of cobalt-60 per tube—which, when manufactured according to the approved specifications, may be distributed to persons not having specific licenses.

AEC REGULATION FOR LICENSING OPERATORS OF REACTOR CONTROLS BECOMES EFFECTIVE

A regulation covering licensing of persons responsible for handling the controls of reactors and other nuclear facilities used in the civilian atomic energy industry was published in the Federal Register on January 4, 1956 by the Atomic Energy Commission. The regulation became effective 30 days after publication.

The regulation, entitled "Operators' Licenses," was announced last June as a proposed rule. Its effective date was postponed to give interested persons opportunity to comment. The regulation applies only to controls which might, if improperly handled, result in the release of dangerous amounts of radioactive material.

An applicant for an operator's license must pass an operating test and a written examination to show his understanding of the general design and characteristics of the facility for whose safe operation he will be responsible. Depending on the scope of his license, he must be acquainted with general operating procedures, control and safety mechanisms, control-station instruments, the emergency shutdown system, and the purpose and function of radiation monitoring equipment applicable to the operation. The applicant must also pass a medical examination.

An operator's license is required only for the person who has the authority and responsibility for deciding how and when controls shall be manipulated, and who works the controls himself or directs someone else to do so in his presence.

An operator's license may be limited or broad in scope. The operator may be licensed to handle only specified controls of a de-

signated facility or class of facility, or the license may cover all controls of a designated facility or class of facility.

Procedures for giving written examinations and operating tests are not prescribed in the regulation. These will be handled administratively by the Commission's Division of Civilian Application. There are no special educational requirements. It is expected that in many cases applicants will have qualified through on-the-job training.

AEC PROGRAM TO ENCOURAGE PRIVATE INDUSTRY TO BUILD AND OPERATE CHEMICAL PROCESSING PLANTS

The Atomic Energy Commission announced early in January a program to encourage private industry to build and operate plants for the chemical processing of irradiated fuel elements from research and power reactors, as a further step toward private ownership of atomic energy facilities for peaceful uses.

Chemical processing plants constitute an integral portion of the fuel cycle of nuclear reactors. They perform the operations of recovering the fissionable and fertile materials present in the irradiated fuel elements for re-use, and of placing the radioactive fission products in disposable or useable forms. So far, these operations are being performed only by Government-owned plants at various Atomic Energy Commission sites.

It is the policy of the Commission to encourage industry to build its own plants for these purposes. The goal is to have commercial processing plants in operation as it becomes necessary to process fuel elements from privately-owned power reactors. The Atomic Energy Commission will make available (1) Commission technology in the field of chemical processing to interested firms, and (2) limited amounts of certain irradiated fuel materials from AEC reactors for processing by industry, to the firms which submit acceptable proposals to the Commission at a date to be specified, about 18 months from now. Commission facilities may also be utilized by private firms for research and development, and training in connection with the chemical processing field. The full costs of such utilization would be defrayed by the user.

In evaluating these proposals, the Commission will take into consideration such factors as the advancement of chemical processing technology which will result from construction and operation of the proposed plant, reasonableness of prices, size and start-up date of the commercial plant, and assurances against abandonment of the project.

Another criterion on which proposals will be evaluated is the manner in which the waste disposal problem will be handled. This criterion has been established in order to give industry the greatest possible incentive to reduce the cost and risks connected with this

operation and to develop economical uses for the radioactive materials which are now generally regarded as waste products.

On the basis of its evaluation, the Commission may select one or more of the proposals which it receives, or it may reject all.

COMPETITIVE BIDDING FOR URANIUM DEPOSIT LEASES

The Atomic Energy Commission announced at the end of 1955 that a system of competitive bidding will be instituted for leasing uranium deposits developed by the AEC on withdrawn public lands and certain other areas under AEC control.

Lands affected include those originally purchased by the Manhattan Engineer District and subsequently transferred to the AEC, and public lands withdrawn from mineral entry at the request of the AEC for exploration purposes.

The AEC does not contemplate extensive leasing of AEC-controlled lands in the near future. The uranium deposits on these lands constitute a reserve to be drawn upon as required. Since ore production from privately-owned properties is being maintained at a high level, it is unlikely that more than a few deposits will be offered for lease in the near future.

Upon determination that a portion of the reserve should be leased, the AEC will award leases on the basis of competitive bids, rather than by the previous system of selecting lessees on the basis of qualifications, including mining experience and financial status. Leases will be awarded to the acceptable bidder offering the highest cash bonus by sealed bid. The royalty rate, work requirements and other conditions will be stated in the invitation to bid. These conditions will be determined by the AEC, and will be based on the estimated size and grade of the deposit and the cost of mining facilities and production.

The selection system which has been in effect has resulted in efficient mining operations on AEC-controlled land, but it was decided that competitive bidding is preferable under present circumstances. The selection system was adopted in 1949, when interest in uranium mining was limited. In recent years, interest in obtaining leases has increased greatly, and the number of qualified applicants has materially exceeded the number of deposits available for lease. This made the selection system difficult to apply. No new leases have been issued since the end of 1953.

One of the reasons for establishing the selection system in 1949 was that information relating to the uranium reserves on AEC-controlled lands was classified and could not be stated in invitations to bid. These reserves are less significant in terms of the total domestic production potential today, because of the great increase in known reserves on lands not controlled by the AEC. Therefore, it now will be

possible for bid invitations to include factual data on AEC exploration in individual lease blocks.

Public hearings were held by the AEC at Grand Junction, Colorado, on March 29, 30 and 31, 1955 on procedures for granting leases. Many of those testifying favored either the present system of selection with some modifications, or public drawing from a list of qualified applicants. A few witnesses favored competitive bidding but many of those who recommended other methods specifically opposed competitive bidding.

Careful consideration was given to the views presented at the hearings. However, a full evaluation of all factors led to the conclusion that the public interest would be served best by adopting the more generally accepted procedure of competitive bidding. It would eliminate the problem of making a selection among qualified applicants, would conform to general Government practice in the disposition of public property, and might result in increased revenues to the Government.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS

SPECTACLE LENS TESTER

Precise Evaluation of Spectacle Lenses

With the aid of an instrument developed by the National Bureau of Standards, it is now possible to measure both central and marginal powers of a spectacle lens with accuracy. This instrument, known as the Spectacle Lens Tester, was designed by Dr. F. E. Washer of the NBS staff in connection with a study[1] of eyeglass lenses for the Veterans Administration. In operation it simulates the refractive effect of the various parts of the lens under study upon the human eye. Although the Spectacle Tester is basically a research tool, its essential principles have been utilized to design marginal-power attachments[2] for the standard vertex-power instrument used by practicing opticians.

The earliest spectacle lenses had spherical surfaces only. However, when the existence of astigmatism was established, it was found that a combination of spherical and cylindrical surfaces improved vision, particularly in the axial region. Thus lens prescriptions specify a correction in terms of both spherical and cylindrical power measured in diopters. This power is what the layman refers to when he speaks of the "strength" of his glasses.

The problem of achieving simultaneous accurate correction at all points on a lens is complex. When only spherical power is involved, it is possible to determine the proper curvature of front and rear surfaces to yield zero marginal astigmatism for a specified object distance over a definite range. But for lenses having both spherical and cylindrical power, the problem of simultaneous marginal and axial correction is more difficult. An almost infinite number of lens shapes is possible. However, in practice a selected series of base curves has been found adequate for visual correction.

Each year the Veterans Administration purchases large quantities of spectacle lenses. To insure that the lenses received provide as excellent correction of vision as practicable, the VA requested the Bureau to develop practical specifications with respect to actual performance of both center and edge and the degree of marginal variation that might reasonably be allowed.

While the accuracy of a spectacle lens can be determined rather easily at the optical center, the determination is much more difficult

[1] For further technical details, see "Instrument for Measuring Marginal Power of Spectacle Lenses," by Francis E. Washer, *J. Opt. Soc. Am.*, Vol. 45, p. 719 (1955).

[2] For further technical details, see "A Simplified Method of Measuring the Marginal Powers of Spectacle Lenses," by Francis E. Washer, *J. Research NBS*, Vol. 55 (1955), RP 2607.

at other points of the lens. The probable marginal performance of a lens can be predicted on the basis of theoretical considerations; but in actual practice slight variations in the surfaces of otherwise identical lenses can significantly vary their performance. Thus, to obtain data on allowable tolerances, it was necessary to design an instrument that would measure the actual performance of available lenses from various makers.

Ultimately the Spectacle Tester was developed for this purpose. It consists essentially of a short-focal-length lens representing the optical system of the eye, a horizontal microscope, and two collimators. The short-focal-length lens is placed a short distance from the eyepiece of the microscope. This part of the assembly is mounted on an instrument table in such a way that it can rotate through an arc of 70°. The spectacle lens to be tested is held fixed in front of the microscope. On the other side of the spectacle lens, a movable collimator in line with the microscope swings about the same axis. The collimator contains test patterns representing objects viewed by the eye. A second collimator, fixed at the end of the table, provides an infinitely distant object which serves to determine the optical axis of the entire system. When the viewing device is rotated from its center position, it receives images formed by parts of the spectacle lens that are correspondingly distant from the optical center.

The viewing device can be locked into position every 5°. In each position a dial gage on the microscope registers the movement of the microscope required to focus on the test pattern. This movement can be interpreted to give the strength of the spectacle lens under test at the corresponding viewing angle.

Approximately 300 lenses from various sources have been tested with this apparatus. Although the degree of compliance with specifications did not vary significantly among the suppliers, it was sometimes found that lenses having identical power at the optical center varied by as much as 0.50 diopter in the marginal areas. And this variation itself is subject to change as the object distance increases from 0.25 meter to infinity.

The Spectacle Tester is well adapted to detailed study of all the visual properties of spectacle lenses, but it would be unnecessarily elaborate for routine testing of marginal powers. The Bureau has therefore designed attachments that permit marginal-power measurements on the standard vertex-power measuring instrument. The latter device is generally a small portable assembly that provides for clamping the spectacle lens between a collimator and a telescope mounted on a fixed axis. Such an instrument when unmodified can measure power at the optical center of a lens only.

The NBS attachments include a small hemispherical seating surface with a center opening and a clamping device to hold the lens under

test against the hemisphere. The radius of the seating surface is 27 mm., the value customarily accepted as the axial distance separating the back surface of the spectacle lens and the center of rotation of the eye.

For measurement of marginal power at, for example, an angle of 30° from the axis of the lens, a dot is marked on the hemispherical surface to locate a point 30° from the axis. The optical center of the lens under test is then pressed against this dot, so that a point 30° from the center of the lens is now opposite the center opening. The marginal power of the lens at this point can then be measured. Because of the prism power introduced by tipping of the lens with respect to the opening, an additional modification was introduced. This is a prism attachment which brings the emergent light beam into the field of view of the observing telescope. All three of the attachments are designed to fit any standard power-measuring instrument and will not prevent use of the instrument for measuring axial power.

PREPARING THIN ASPHALT FILMS BY SPINNING

A rapid method for preparing thin asphalt films[1] for test specimens has been developed by the National Bureau of Standards in connection with a study of asphalt weathering properties. By this method, thin films are readily obtained by pouring molten asphalt on a rapidly spinning disk; the variables in the procedure can be controlled to produce film thicknesses from 0.0005 to 0.050 in. The procedure was developed by L. R. Kleinschmidt of the Bureau's floor, roof, and wall coverings laboratory.

In the study of asphalt degradation, many replicate test specimens are usually prepared for exposure either to outside weathering conditions or to light, heat, and water in accelerated exposure test machines. In some of the tests at NBS where specific coating thicknesses greater than 0.015 in. are required, the specimens are prepared by either the doctor blade or the hydraulic press method. However, these methods are satisfactory only when coatings thicker than 0.015 in. are desired.

In an effort to prepare thinner films, another method was sought, and the one originally developed for paint and varnish films by pouring such materials onto a spinning disk[2] was examined. This process was adapted to the Bureau's needs by providing a means for preheating the aluminum test panel to insure good bonding, and by heating the asphalt to an appropriate pouring consistency. The spinning-disk method is also applicable to other materials that have narrow softening-point ranges, rather than definite melting points, such as paraffin or stearic acid rosin.

[1] "Preparation of Thin Bituminous Films by Spinning," L. R. Kleinschmidt, *ASTM Bulletin*, No. 193, Vol. 53, Oct. 1953.

[2] "Some Physical Properties of Paints," P. H. Walker and J. G. Thompson, *Proc. Am. Soc. Testing Mat.*, Vol. 22, Part II, 464 (1922).

The equipment consists simply of a $\frac{1}{3}$-hp. shunt-wound d-c. motor, mounted on end, with a shaft extension at the upper end to which the test panel is fastened. The speed of the motor is regulated by two slide-wire resistors, one connected in series with the armature and the other in series with the field. Under the panel is a ring gas burner to heat the panel to its working temperature; the heat insures good bonding between the panel and the asphalt. An asbestos shield under the burner prevents asphalt from dripping onto the motor. A shield around the equipment retains material thrown from the disk during the coating operation.

The 4-in. aluminum disk test panel is prepared for coating by rubbing with fine steel wool saturated with water to provide a mat surface. It is then washed with mineral spirits, dried, and weighed. A screw through a hole in the center of the disk holds it firmly to the motor shaft.

For uniform films, occluded air is removed from the asphalt by heating until fluid and placing under a vacuum for several minutes. This cycle is repeated until there is no evidence of foaming immediately after the material is placed in the vacuum.

To prepare an asphalt film, the aluminum disk is first fastened to the motor shaft and centered to be free of vibration. The disk is then heated, while rotating, by the ring burner to about 200 to 220° F. The flame is extinguished, and molten asphalt is poured onto the rapidly spinning disk, starting near the center and working toward the edge. As soon as the spinning disk is completely covered, it is stopped and removed from the motor shaft.

Coating thickness is determined indirectly from the weight, density, and area of the asphalt coating. The thickness of the coating depends mainly on the speed of the disk and the consistency of the molten asphalt. Usually only a few trial panels are sufficient to determine the working tolerances of speed and temperature. Once these are determined, the process is easily repeated to produce many panels with coatings varying in thickness by small increments. Results of accelerated weathering tests on panels prepared by the spinning method reveal that the coating is significantly uniform over the entire area to exhibit a uniform pattern of deterioration.

THE FRANKLIN INSTITUTE

MINUTES OF THE STATED MEETING
February 15, 1956

The Stated Monthly Meeting of The Franklin Institute was held on February 15, 1956, in the Lecture Hall. S. Wyman Rolph, President, called the meeting to order at 8:15 P.M. Approximately 350 members and guests were in attendance.

In the absence of the Secretary, Cecil M. Waterbury, Assistant Secretary, read the minutes of the December Stated Meeting and the Annual Meeting. There being no corrections, changes or additions to either, they were approved. Minutes of both meetings will appear in the February issue of the JOURNAL.

The Assistant Secretary then read the annual report of the Trustees of the Elliott Cresson Medal Fund to the Institute, as follows:

ELLIOTT CRESSON MEDAL FUND

Report of the Trustees to The Franklin Institute
January 18, 1956

The deed of gift under which Elliott Cresson, in 1848, gave $1000.00 to two trustees, the income of which was to furnish medals to be awarded by The Franklin Institute, provided that the trustees should present to the Annual Meeting of the Institute, in January, a report showing the principal of the fund and its income and expenses during the preceding year.

Principal Account		$4,304.73
Invested as follows:		
$4000 U. S. Treasury 2½% bonds due 6/15/1962–67 at book value	$4,102.69	
Cash in Western Savings Fund Society	202.04	
	$4,304.73	
Income Account		
Income for 1955		
Interest on bonds (less amortization)	$ 126.29	
Interest on bank balance	4.62	$ 130.91
Expenses		
Insurance of medal dies, one gold medal and case, certificate and engrossing of same, and audit of books		165.89
Over-expenditure of income for the year		(34.98)
Unexpended income at January 1, 1955		2,268.46
		$2,233.48
Invested as follows:		
$2000 U. S. Treasury 2½% bonds due 6/15/62–67 at book value	2,051.61	
Cash in Fidelity-Philadelphia Trust Company	181.87	
	$2,233.48	
Combined Principal and Income	$6,538.21	

(s) *Henry B. Allen*
HENRY B. ALLEN
(s) *John Frazer*
JOHN FRAZER
Trustees

The President then introduced the speaker of the evening, Dr. W. F. G. Swann, whose talk on "Nature and the Mind of Man" was enthusiastically received. Dr. Swann's address will be published in a later issue of the JOURNAL.

The President then presented His Excellency, Henry de Torrente, Minister to the United States from Switzerland, whose greetings and brief remarks were highlights of the dinner preceding the meeting.

The meeting adjourned at 9:45 P.M.

CECIL M. WATERBURY
Assistant Secretary

MEMBERSHIP

FIRST "SILVER" DINNER

On February 9, 1956, the Institute honored those members who had completed from 25 to 49 years of continuous membership. At this first "Silver" Dinner, 58 of the 211 eligible Silver Members were guests at a reception and dinner in Franklin Hall. The "oldest" Silver Member present was W. M. C. Kimber who joined in 1908. One of the interesting highlights was the presence of three generations of the Colvin family: Fred H. Colvin, a Gold Member (1888); his son, Charles H. Colvin, a Silver Member (1918); and Margaret Ann Colvin, his granddaughter. It is a tradition in the Colvin family to present a Life Membership in The Franklin Institute to the members of the family as they reach 21 years of age.

Each honored guest received an attractive, initialed paper weight in which was embedded a silver quarter minted in the year in which he joined the Institute. Another favor was a chromium tray, gift of the Doehler-Jarvis Division of the National Lead Co.

Following dinner, Morton Gibbons-Neff, Chairman of the Membership Committee and himself one of the honored guests, introduced the Silver Members who were present. He also announced that the total membership to date was 7129.

S. Wyman Rolph, President of the Institute, introduced John S. Burlew, newly elected Executive Vice President, who outlined the relationship of members to the future program of the Institute. He expressed the hope that, as our program continued to expand, it would be of increasing benefit both to the technical and the nontechnical members.

The Colvin Family and Mrs. Milton Price Harley, Director of Membership, at the Silver Dinner. L. to r.: Charles H. Colvin, Mrs. Charles H. Colvin, Mrs. Harley, Miss Margaret Ann Colvin and Fred H. Colvin.

The following are Silver Members, having belonged continuously for twenty-five years or more. The dates are years of election to membership.

1907
Darthela Clark
Frank Shaw Clark

1908
*W. M. C. Kimber
John B. Rumbough

1909
Theobald F. Clark
Walton Clark, Jr.
*James McGowan, Jr.
George Missimer, Jr.
T. Edward Ross

1910
*Richard B. Brown
*Joseph S. Hepburn
Joseph W. Lippincott
*J. D. Shattuck
J. M. Weiss

1911
Seth B. Capp
W. H. Fulweiler
Charles Penrose

1912
*James Barnes
Morris Llewellyn Cooke
*Edwin Elliot
*Walter Palmer
*Julian S. Simsohn
*Howard S. Worrell

1913
Edward Bartow
Sterling H. Bunnell
Irenee duPont
S. B. Eckert
Ralph E. Flanders
N. E. Funk
*Lionel F. Levy
E. Mallinckrodt, Jr.
Frank M. Masters
Franklin P. McConnell
William Maul Measey
*W. Chattin Wetherill
*D. Robert Yarnall

1914
Russell L. Brinton
*George S. Crampton
Ernest L. Huff
K. G. Mackenzie
George Wharton Pepper

1915
Thomas D. Cope
John C. Cornelius, Jr.
H. Jermain Creighton
Thomas W. Elkinton
Richard Howson
W. Wallace McKaig

1916
Henry B. Allen
James G. Detwiler
Zay Jeffries
*Thorsten Y. Olsen
*Frank H. Sauer
B. E. Shackelford
H. B. Spencer
*Arthur Synnestvedt
Leo Wallerstein
Charles N. Weyl

1917
A. D. Chambers
*Francis J. Chesterman
Walter S. Crowell
P. T. Dashiell
William J. Fitzmaurice, Jr.
Rolfe E. Glover, Jr.
*Harold Goodwin, Jr.
*Arthur W. Lowe
Frank S. MacGregor
Francis F. Milne, Jr.
C. H. Quinn
*Sylvan D. Rolle
Robert L. Wood
Henry Woodhouse

1918
*Charles H. Colvin
Walter O. Snelling

1919
Charles E. Brinley
Henry Colvin, 2nd

1919 (cont.)
E. A. Eckhardt
George W. Furness
Frank H. Griffin
Hiram S. Lukens
H. Conrad Meyer
J. Howard Pew
Edmund G. Robinson
L. K. Sillcox
W. Leigh Smith
John Sealy Townsend

1920
Robert Cameron Colwell
Francis W. Hartzel
Chester Lichtenberg
*P. S. Lyon
Haviland H. Platt
*Carl D. Pratt

1921
Roland L. Andreau
Leonard T. Beale
J. Ed. Brewer
Arthur L. Day
*Frederic Palmer, Jr.
*Howard Stoertz
James Stokley
Edward R. Weidlein
S. Weinberg

1922
C. Douglas Galloway
Joseph F. Greene
C. E. K. Mees

1923
Henry Clay Gibson
Howard S. Levy
William C. Melcher, Jr.
John F. Metten
Jessie A. Rodman
Edwin G. Sagebeer
*Coleman Sellers, 3rd
*H. Birchard Taylor
*Francis B. Vogdes
*Joseph J. Vogdes

1924
*Peter Abrams
*H. Carl Albrecht

1924 (cont.)
Clement Starr Brinton
*Lee Davidheiser
William G. Ellis
*T. R. Harrison
*Valentine Hiergesell
*Karl F. Oerlein
Edward B. Patterson
Harold Pender
Nicholas G. Roosevelt
Alfred O. Tate
*Walter C. Wagner
*James Lloyd Weatherwax
Alexander Wilson, 3rd
*William Zimmermann

1925
Jack G. Binswanger
William L. Brown, 3rd
Marion Eppley
John Graham Foley
J. V. Giesler
*C. R. Kraus
J. Kenneth W. Macalpine
*H. F. Porter
W. F. G. Swann

1926
Charles B. Bazzoni
Neils Bohr
O. E. Buckley
William Findlay Downs
Henry C. Evans
*Edward L. Forstall
Lewis H. Hendrixson
Charles S. Leopold
Alfred L. Loomis

1926 (cont.)
J. H. Manning
William Clarke Mason
Clement B. Newbold
O. M. Patton
Charles S. Redding
Dexter N. Shaw
*Sydney L. Wright
Charles S. Wurts, Jr.

1927
William Adam
T. K. Cleveland
Milton W. Deisley
William DeKrafft
Hiram B. Ely
*Leslie Griscom
John W. Harsch
Alfred Iddles
John Van Gasken Postles
Philip Sporn
*Charles A. Stanwick
*Charles A. Young

1928
William R. Dohan
Walton Forstall, Jr.
C. W. Hansell
Walter A. MacNair
*Fred P. Nabenhauer
Joseph N. Pew, Jr.
William Rogers, Jr.
Frank N. Speller

1929
*N. E. Bonn
*M. M. Borden

1929 (cont.)
*Bernard Davis
*Rupen Eksergian
*Edward C. Haines
Isaac Harter
Malcolm Lloyd Hayward
Linn Helander
Randall Morgan, III
Harold F. Pitcairn
Edmund Rowland
Lawrence Saunders
A. Kelvin Smith
I. Melville Stein
William Stericker
*Harden Franklin Taylor
Jacques L. Vauclain
Albert J. Williams, Jr.
Arthur M. Wilson, Jr.
C. T. R. Wilson
*Enos E. Witmer

1930
Mildred Allen
William M. Barret
Aldus Fogelsanger
John Gardiner, Jr.
*Morton Gibbons-Neff
Norman R. Gibson
*Carroll Hodge
*Walter J. Lehman
R. P. Long
*S. B. Morehouse
William C. Peterman
George F. Pettinos
Max Trumper
David P. Wheatland
G. E. Wiltbank

The following are Gold Card Members, having belonged continuously for fifty years or more:

Alexander Sellers '84
William Henry Bower '85
*Fred H. Colvin '88
*G. H. Clamer '91
J. H. Granberry '95
Edward Woolman '95
E. A. Muller '99
C. C. Tutwiler '99
James M. Caird '01
Kern Dodge '02
John P. B. Sinkler '02
Charles H. Howson '03
Frank S. Busser '04
C. Mahlon Kline '04
George R. Hall '05

* Present at the Silver Dinner.

ACTIVE MEMBERS ELECTED BY THE BOARD OF MANAGERS

February 15, 1956

ACTIVE FAMILY

Irvine E. Herron — Benson Krieger

ACTIVE

Fred S. Bateman
Oren R. Bingham
Henry F. Blankenbiller
Thomas H. Chilton
Carl F. Clancy
Everett N. Cliff
John R. Connolly
Richard L. Corbin
Arie DeKort
Leonard C. Dill, Jr.
Leighton Dunning
Charles J. Finnaren
Eugene Frank
John Frey
Vincent B. Fuller
Byron Gates
John P. Green
Robert D. Heath
Samuel Hindin
P. C. Iverson
Mrs. J. Cary Jones
Marion Stanley Kapelski
Ralph J. Knoll
Erwin T. McCain
Thomas Moore, Jr.
S. John Oechsle, Jr.
Chester L. Osterman
Ted Reinhart
Harry Renner, III
George T. Sharp
Harold L. Small
Augustus M. Wessels
Edward M. Wilson
William F. Zellers

ACTIVE NON-RESIDENT

George E. Gardner
Irving Halev
Joseph A. LaFauce
William E. Salomon

NECROLOGY

William A. Campion '42
Oliver L. King '49
Horace P. Liversidge '10
Mrs. Lewis Neilson '38
Edwin D. Rattigan '52
Charles J. Rhoads '35
Oscar Schaefer '36
Carleton H. Schlesman '37
Robert Wooler '50

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 387 items have been added the past month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, Fridays, and Saturdays; and 2 P.M. until 10 P.M. on Wednesdays.

RECENT ADDITIONS

AERONAUTICS

BURGER, ALEWYN PETRUS. On the Asymptotic of Wave Propagation and Oscillation Problems. 1955.

FAY, JOHN. The Helicopter and How it Flies. 1955.

PENNER, S. S. Introduction to the Study of Chemical Reactions in Flow Systems. 1955.

U. S. NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Index to N. A. C. A. Technical Publications. 1955.

AGRICULTURE

ROSE, G. J. CROP PROTECTION. 1955.

ARCHITECTURE AND BUILDING

KAY, N. W., ED. The Modern Building Encyclopaedia. 1955.

BIOGRAPHY

CAJORI, FLORIAN. The Chequered Career of Ferdinand Rudolf Hassler; First Superintendent of the United States Coast Survey. 1929.

BIOLOGICAL CHEMISTRY

BIOCHEMICAL SOCIETY. Symposia. No. 1, 3, 5–12. 1948–1954.

CHEMISTRY AND CHEMICAL TECHNOLOGY

Advance in Catalysis and Related Subjects. Vol. 7. 1955.
BRABERS, MARTINUS JOANNES. Electronische Structuur van Metalen en Overspanning. n. d.
DENBIGH, KENNETH. The Principles of Chemical Equilibrium. 1955.
FRANCIS, WILFRID. Boiler House and Power Station Chemistry. 1955.
MCKEEN, JOHN E. Our Smallest Servants; the Study of Fermentation. n. d.
MASKE, R. H. F. The Alkaloids. Vol. 5. 1955.
Organic Syntheses. Vol. 35. 1955.
POLEY, JOHANNES PHILIPPUS. Microwave Dispersion of Some Polar Liquids. 1955.
Progress in Organic Chemistry. Vol. 3. 1955.
YARWOOD, J. High Vacuum Technique. 1955.
ZAHN, E. A. Scientific Paint Evaluation. 1955.

CIVIL ENGINEERING

HENNES, ROBERT G. AND EKSE, MARTIN I. Fundamentals of Transportation Engineering. 1955.
MATSON, THEODORE M.; SMITH, WILBUR S. AND HURD, FREDERICK W. Traffic Engineering. 1955.

ELECTRICITY AND ELECTRICAL ENGINEERING

MATHEWS, P. Protective Current Transformers and Circuits. 1955.
REED, MYRIL B. Electric Network Synthesis; Image Parameter Method. 1955.
VALKENBURG, M. E. VAN. Network Analysis. 1955.

ENGINEERING

MOTE, M. W., JR. AND FROST, P. D. Report on the Engineering Properties of Commercial Titanium Alloys. 1955.

FOOD

LOESECKE, HARRY WILLARD VON. Drying and Dehydration of Foods. Ed. 2. 1955.

GENERAL

HULBERT, JAMES ROOT. Dictionaries: British and American. 1955.

GEOLOGY

NATIONAL RESEARCH COUNCIL. DIVISION OF EARTH SCIENCES. Annual Report 1954–55. 1955.

HOROLOGY

HUMBERT, B. The Chronograph. Ed. 2. 1954.
HUMBERT, B. Modern Calendar Watches. 1954.
JENDRITZKI, H. The Swiss Watch Repairer's Manual. 1953.

INDUSTRIAL MANAGEMENT

GEPPINGER, H. C. Dimensional Motion Times. 1955.

MANUFACTURE

ENVEDY, RALPH. Handbook of Barrel Finishing. 1955.

MARINE ENGINEERING

SMITH, R. MUNRO. The Design and Construction of Small Craft. 1924.

MATHEMATICS

BUSEMANN, HERBERT. The Geometry of Geodesics. 1955.
HALL, DICK WICK AND SPENCER, GUILFORD L. Elementry Topology. 1955.
MONTGOMERY, DEANE AND ZIPPIN, LEO. Topological Transformation Groups. 1955.

MECHANICAL ENGINEERING

SMITH, G. GEOFFREY. Gas Turbines and Jet Propulsion. Ed. 6. 1955.
STEWART, HARRY L. AND JEFFERIS, FLOYD D. Hydraulic and Pneumatic Power for Production. 1955.
TOWN, H. C. Hydraulic and Pneumatic Operation of Machines. 1956.

METALLURGY

FISCHER, HELLMUTH. Elektrolytische Abscheidung und Elektrokristallisation von Metallen. 1954.
INSTITUTE OF METALS. Metallurgical Abstracts. Vol. 21. 1954.

OPTICS

LE POOLE, JAN BART. Some Designs in Electron and Ion Optics. 1954.

PETROLEUM TECHNOLOGY

LOCHTE, H. L. AND LITTMANN, E. R. The Petroleum Acids and Bases. 1955.
NATIONAL PETROLEUM COUNCIL. COMMITTEE ON OIL AND GAS AVAILABILITY. Petroleum Productive Capacity. 1952.

PHYSICS

BRØNSTED, J. N. Principles and Problems in Energetics. 1955.
CADLE, R. D. Particle Size Determination. 1955.
GUINIER, ANDRÉ AND FOURNET, GÉRARD. Small-Angle Scattering of X-rays. 1955.
JAUCH, JOSEF MARIA AND ROHRLICH, F. The Theory of Photons and Electrons. 1955.
LIN, C. C. The Theory of Hydrodynamic Stability. 1955.
LITTLER, D. J. AND RAFFLE, J. F. An Introduction to Reactor Physics. 1955.
PHYSICAL SOCIETY OF LONDON. Reports on Progress in Physics. Vol. 18. 1955.
RICHTMYER, F. K.; KENNARD, E. H. AND LAURITSEN, T. Introduction to Modern Physics. Ed. 5. 1955.
SCHULTZ, MORTIMER A. Control of Nuclear Reactors and Power Plants. 1955.
Solid State Physics. Vol. 1. 1955.
WOOD, A. B. A Textbook of Sound. 1955.

SANITARY ENGINEERING

GURNHAM, C. FRED. Principles of Industrial Waste Treatment. 1955.

SCIENCE

NEWMAN, JAMES ROY, ED. What is Science? 1955.

STATISTICS

SPROWLS, R. CLAY. Elementary Statistics. 1955.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

EISENBUD, LEONARD: Time Dependent Formulation of the Collision Problem in Quantum Mechanics

JONES, E. E.: The Magnetostatic Force on Two Circular Cylindrical Conductors Carrying Uniform Steady Currents

CUNNINGHAM, W. J.: Nonlinear Oscillators with Constant Time Delay

HERRMANN, JACOB AND C. S. ADES: Experimental Verification of Circular Plate Bending Theory

HEYDA, JAMES F.: An Elementary Derivation of the Formula for the Windage Jump of a Spinning Shell

MITCHELL, E. H.: Analysis of Magnetic Circuits with Given D. C. Excitation

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

All of us associated with The Franklin Institute are gratified by the support given by its benefactors in the past. Without their generosity our privately endowed Institute would have been unable to serve industry, the professions, and the public as it has and should.

There is still a continuing and pressing need of contributions and bequests —both for general and specific endowment, and of income to be judiciously used. Your response will be most earnestly appreciated.

Checks should be made payable to The Franklin Institute, and sent to The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pennsylvania.

Where property is transferred, title should be in the name of The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

We shall be glad to supply any additional information regarding gifts and memorials. Please write to the above address, attention of the Endowment Department.

NOTES FROM THE BARTOL RESEARCH FOUNDATION

DECAY OF RHENIUM 188†*

BY

V. R. POTNIS,[1] V. S. DUBEY,[2] AND C. E. MANDEVILLE

The 18-hr. rhenium was formed by slow neutron irradiation of metallic rhenium in the Brookhaven reactor. The quantum radiations have been examined with the aid of coincident scintillation spectrometers. Photopeaks are present at energies of 150, 480, 630, 820, 910, 1130, 1300, 1600, and 1770 kev. The previously reported complexity of the peak at ~630 kev was studied with the application of coincidence technique. The 150 kev gamma ray is found to be in coincidence with 660 kev quantum radiations. In addition to those already known gamma rays, gamma rays have been detected at energies of 1300 and 1770 kev. The relative intensities of the unconverted quantum radiations are 101, 12, 16, 0.3, 6.5, 5.8, 2.7, 2.2, 2.1, and 1 in the order of ascending energy. The angular correlation function of the 480 kev-150 kev cascade has been measured and is given by

$$W(\theta) = 1 - 1.20 \cos^2\theta + 1.34 \cos^4\theta,$$

which is corrected for finite angular resolution of the apparatus. This function is in accord with a 2-2-0 scheme. The extent of anisotropy at 180° suggests that 480 kev transition is a mixture of E2 in M1 to the extent of 99.56 per cent. The mixing ratio was found to be positive, corresponding to a phase difference of 180° between the matrix elements of the two types of transition.

† Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

* Abstract of a paper presented at the New York Meeting of The American Physical Society, January 31, 1956.

[1] Permanent address, Gwalior (M.B.) India.

[2] On leave of absence from Agra College, Agra, India.

Q-VALUE MEASUREMENTS FOR PHOSPHORUS AND CHLORINE†*

BY

D. M. VAN PATTER, C. P. SWANN, W. C. PORTER, AND C. E. MANDEVILLE

Nuclear reaction energies have been measured using a double-focussing magnetic spectrometer at an observation angle of 90°, in conjunction with the *ONR*-Bartol Van de Graaff generator. Energy

calibrations included Po alpha-particles, the $Al^{27}(p,\alpha)Mg^{24}$ reaction energy, and the $Li^{7}(p,n)Be^{7}$ threshold. From an analysis of the measurements for reaction groups from targets containing P and Cl, the following Q-values were obtained.

$$P^{31}(p,\alpha)Si^{28} \quad Q = 1.911 \pm 0.005 \text{ Mev}$$
$$Cl^{35}(p,\alpha)S^{32} \quad Q = 1.851 \pm 0.007 \text{ Mev}$$
$$Cl^{37}(p,\alpha)S^{34} \quad Q = 3.015 \pm 0.011 \text{ Mev}$$
$$Cl^{37}(p,\alpha)S^{34*} \quad Q = 0.886 \pm 0.009 \text{ Mev}$$
$$P^{31}(p,p')P^{31} \quad Q = -1.264 \pm 0.004 \text{ Mev}$$
$$Cl^{35}(p,p')Cl^{35} \quad Q = -1.219 \pm 0.005 \text{ Mev}$$
$$Cl^{35}(p,p')Cl^{35} \quad Q = -1.760 \pm 0.004 \text{ Mev}$$

The identification of the two inelastic proton groups to the Cl^{35} isotope is primarily based on preliminary results of Endt *et al* (1). A survey was also made at $E_p = 3.06$ Mev for inelastic proton groups from P^{31} corresponding to levels from 0 to 1.44 Mev excitation. Only one group ($Q = -1.27$ Mev) was observed, consistent with recent measurements (2) of the gamma radiation emitted from P^{31} bombarded by protons.

(1) P. M. ENDT (private communication).
(2) J. W. OLNESS AND H. W. LEWIS, *Phys. Rev.*, Vol. 99, p. 654(A) (1955).

† This research was supported by the U. S. Air Force, through the Office of Scientific Research of the Air Research and Development Command.

* Abstract of a paper presented at the New York Meeting of The American Physical Society, January 31, 1956.

UPPER LIMITS TO THE LIFETIMES OF EXCITED STATES IN Al^{27} AND Na^{23}† *

BY

C. P. SWANN AND W. C. PORTER

The recoil technique described by Devons *et al* (1) has been applied to the 440 kev level of Na^{23}, the 840 kev and 1010 kev levels of Al^{27}, and the 108 kev level of F^{19}. In all cases the excited nuclei were produced by inelastic proton scattering. The result obtained for the F^{19} level agrees with previously reported work (2). For the other states only upper limits could be established. The mean lives of the two levels in Al^{27} are shorter than 10^{-10} sec whereas that for the level

in Na^{22} is shorter than 2.5×10^{-11} sec. From the cross section for the Coulomb excitation (3) of this level, the partial electric quadrupole mean life can be calculated, providing the spins of the ground state and excited state are known. With the ground state spin of $3/2+$ and an excited state spin of $5/2+$, one obtains a lifetime of 1.8×10^{-10} sec., which is well above our limit. This, therefore, indicates that the 440 kev transition in Na^{22} must be a mixture of magnetic dipole and electric quadrupole radiation with the magnetic dipole component at least seven times stronger than the electric quadrupole component.

(1) S. DEVONS, H. G. HEREWARD AND G. R. LINDSEY, *Nature*, Vol. 164, p. 586 (1949).
(2) J. THIRION, C. A. BARNES AND C. C. LAURITSEN, *Phys. Rev.*, Vol. 94, p. 1076 (1954).
(3) G. M. TEMMER AND N. P. HEYDENBURG, *Phys. Rev.*, Vol. 94, p. 426 (1954).

† Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

* Abstract of a paper presented at the New York Meeting of The American Physical Society on January 31, 1956.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

DILATOMETER FOR STUDYING THE DENSIFICATION OF POWDER COMPACTS

BY

I. G. GREENFIELD, R. L. SMITH AND J. L. RUTHERFORD

INTRODUCTION

The generally accepted meaning of the term "sintering," as applied in the metallurgical sense, is the formation of bonds between metal particles, accompanied by a densification of the metal-void system under consideration. This phase of metallurgy is of considerable practical and fundamental interest. The practical interest stems from the vast volume of powder-metallurgical products being manufactured and the increased use of powder metallurgy in the solution of industrial problems. The fundamental interest arises from an incomplete understanding of the physical processes involving the atom movements that enable the phenomena of sintering to occur.

In order to study the sintering process, investigators have designed various types of experiments. These involve the measurement of such parameters as the rate of formation of metal bridges between particles, or the rate of densification of a metal-void compact. There is considerable argument concerning the relative merits of the various types of sintering experiments. However, these arguments deal primarily with the problem of whether or not a given experiment is capable of producing information of fundamental significance.

Aside from fundamental considerations, it is necessary to look at the sintering phenomena from a practical viewpoint. Densification studies on powder compacts are particularly useful in providing data that can be used to aid in the evaluation of powder-metallurgical processes.

The densification of a powder compact during sintering may be followed continuously by a dilatometer, or it may be observed in steps by removing specimens from the sintering furnace at given intervals. The dilatometer method and its instrumentation are described in this report. The primary advantages of this method are that it gives a continuous curve and is amenable to autographic recording. The basic information obtained from the dilatometer is the change in length of a powder compact during sintering. The sintering conditions are usually carried out isothermally but, of course, may be conducted non-isothermally.

GENERAL DESCRIPTION AND USE OF THE DILATOMETER

A schematic diagram of the dilatometer is shown in Fig. 1. The change in length of the compact is followed by a Vycor tube, *A*, which is connected to an iron core, *B*, of a linear differential transformer. The iron core is supported by two cantilever springs, *C*, which prevent lateral motion of the core and decrease the weight of the core on the specimen. The pick-up differential transformer consists of three coils wound on an insulating spool. The center coil, *D*, is energized with alternating current which causes a flux to be produced in the two secondary coils, *E*. The coils are arranged so that the directions of the currents are opposite and balance each other for a particular position of the iron core. The secondary coils are connected to a

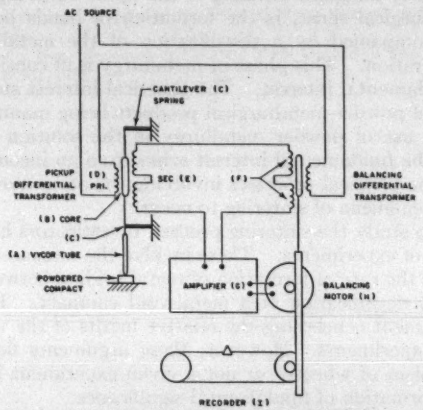


FIG. 1. Schematic diagram of dilatometer.

matching pair of secondary coils, *F*, in a balancing differential transformer. When the position of the core in the pick-up is the same as the position in the balancing transformer, the voltage that appears across the input of the amplifier, *G*, is small. However, if the pickup core is moved vertically, a phase unbalance occurs. This unbalance is fed into the amplifier which controls a motor, *H*, that moves the core of the balance transformer until a null voltage is obtained. The movement of the core of the balance transformer is transmitted mechanically to a pen, *I*, on a strip chart recorder.

The design of this instrument allows continuous recording with a sensitivity range that can be adjusted from a full scale travel equal to 0.005 in. to a full scale travel equal to 0.105 in. It can be easily seen that at the highest sensitivity the limitations of the instrument

arise through mechanical parts rather than through the differential transformer mechanism. The differential transformer, amplifier, balancing mechanism and recorder are combined in an instrument which the Schaevitz Engineering Company of Camden, N. J. produces.

The temperature of the compact is observed on a precision Rubicon potentiometer which is connected to a chromel-alumel thermocouple, placed close to the surface of the specimen. The thermocouple (see Fig. 2) is contained in a 7-mm. Vycor follower tube that extends to a Lavite disc, *A*, on the top of the compact, *B*. A Lavite disc is also

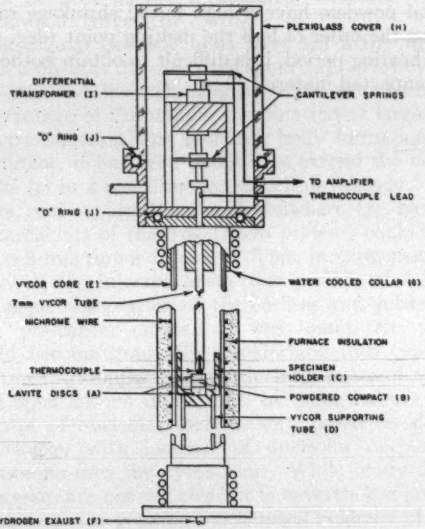


FIG. 2. Construction details of dilatometer.

used below the specimen to prevent the sintering of the compact to the specimen holder, *C*.

The furnace core is a 2¼-in. diameter by 18-in. long Vycor tube which is wound with nichrome wire for a length of 8 in. The base of the tube is closed with a brass, water-cooled plug which contains the hydrogen exhaust tube, *F*. A brass, water-cooled collar, *G*, and flange are mounted on the top of the tube. The hydrogen enters the furnace through a port in the side of the collar. To insure a closed system, a plexiglass cover, *H*, is placed over the transformer, *I*, and sealed to the brass flange by means of an O ring, *J*.

Usually it is desirable to conduct isothermal sintering experiments. With the type of equipment described here it is necessary to put the specimen in the furnace before bringing it up to temperature. The initial heating imposes non-isothermal conditions, thus it is desirable to get the specimen up to temperature as rapidly as possible. With this equipment it is possible to heat the specimen to 800° C. in 8 min. Of course, the first few minutes of the experiment cannot be analyzed as isothermal data. However, this is not troublesome at low temperatures or for high compacting pressures since very little sintering takes place during this period. On the other hand, uncompacted specimens of some metal powders have a high initial shrinkage rate at temperatures only on the order of half the melting point (deg. C.). Because of the initial heating period, it is difficult to obtain isothermal sintering data on uncompacted material.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, M. D., FOUNDER
WILLIAM G. BATT, D. Sc., DIRECTOR

Seminar on Transmission Studies on Renal Adenocarcinoma of the Frog.—DR. WILLIAM R. DURYEE of the Department of Physiology, George Washington University School of Medicine, Washington, D. C. addressed the Seminar of the Biochemical Research Foundation on Thursday afternoon, November tenth.

Studies on animal carcinogenesis have led many investigators to the concept of a virus as the causative agent (1). However the cellular mechanisms involved in such changes have not been made clear. With the advantage of the unique combination of large cell size, presumed virus transmission, and inclusion body formation found in the frog kidney tumor, it has been possible to extend the notable pioneer work of Lucké (2) in a new direction of cell physiology. Experiments[1] reviewed here, and reported in detail elsewhere (3), have shown that renal adenocarcinoma of the frog (*Rana pipiens*) could be induced by injections of cell-free tumor filtrates. This, in turn, made possible, by serial sacrifice of the injected hosts over periods of 1.5 to 7 months *direct* microscopic observation of the earliest and subsequent changes toward the "pre-cancer" state. It was found that normal kidney tubules could become gradually transformed into typical malignant acinar structures. Parallel and interlocking series of observations on induced and spontaneous tumor cells in tissue culture have led to a general concept of nucleolar involvement, based on slow changes in nuclear physiology with increase of nucleolar output through the nuclear membrane into the cytoplasm. While many details of these complex processes are not yet clear, it is nevertheless possible to relate the observations to the growing biochemical evidence of a DNA-RNA-Protein relationship, envisaged by Caspersson (4), Mazia (5), and others.

Tumors of various sizes and degrees of differentiation were ground, cells pulverized with vibrated pyrex beads, and the extract centrifuged twice at 2000 RPM. The final supernate was passed through an 02 Selas filter (max. pore size 0.85 micron). Injections of tumor filtrate were made directly into host kidneys, using aliquots of the same syringefuls to insure adequate sampling and to provide mutual controls. From each original donor and from the induced tumors parallel series of long-term tissue cultures were made to compare directly with one another in living and fixed and stained conditions, and to compare with serial sections of donor tissue and injected kidneys.

[1] The research was carried out while the author was a member of the staff of the National Cancer Institute, U. S. Public Health Service, Bethesda, Md.

Briefly summarized the results of these experiments showed that filtrate injections yielded identifiable adenocarcinomas in 17 per cent of the animals. However approximately 44 per cent of the hosts were negative, showing clear indications of an immune type of reaction. In the remaining 39 per cent some degree of pre-cancerous change was found, grading from nearly normal to multi-layered, hyperplastic tubule, and acinar-like patterns. The existence of distinct pre-cancer states in different degrees in the latter group is important in throwing light on the cytological mechanisms disturbed by Lucké's postulated "organ-specific virus."

In the parallel series of tissue cultures studied with phase-contrast optics and by micromanipulation (6), and also by Feulgen and other staining procedures, significant changes in nuclear and nucleolar activity were observed. Atypical DNA granules in the form of chains, coacervate droplets and irregular bodies were seen and photographed inside many of the nucleoli, but not in all. In the majority of cultures, older than 2 months, fewer Feulgen-positive bodies remained. By means of sequence photomicrographs taken with phase-contrast objectives at high magnifications every 15 minutes over several hours, an interesting new type of nucleolar hyperactivity resulting in nuclear extrusion or "pumping" was observed in nearly every cell. This process, recognizable on a greatly reduced scale in other types of normal cells, was designated as *the nuclear pump*. Activity was clearly related to the degree of proliferation of the tissue or cells concerned. Staining reactions showed that the resulting cytoplasmic inclusion bodies, always surrounded by a halo, or clear area, were not DNA, but possible RNA-protein. Evidence for halo-formation inside the nucleus before extrusion was found. Occasionally DNA granules could be seen emerging inside the inclusion mass. Evidence for similar nucleolar hyperactivity was likewise adduced from sections of all spontaneous and induced tumors.

Spreading of the adenocarcinoma throughout the kidney appeared frequently in multiple loci to be the result of infection as well as invasion. Enlarged, hyperactive nucleoli, mitoses in the tubule walls, increased basophilia, change in cell shape from cuboidal to columnar type and infolding of multi-layered cells were typical in all advanced pre-cancerous areas. Transformation of normal proximal tubules into differentiated adenocarcinomatous acini was demonstrable in numerous instances, and the degree of differentiation was, to some extent, comparable to the degree of malignancy (amount of metastasis) of the donor.

Thus the evidence is against the all-or-none phenomenon in the genesis of this tumor. It favors strongly the virus theory of Lucké, and an exogenous catalyst concept. While the purpose of this study was not the biochemistry, but the biology of the tumor, it is not un-

reasonable to suggest that the DNA-RNA-Protein chain of synthesis is furnishing the observable marked increase in cell size and number. These findings may be of value in explaining results of other investigators in the fields of virus pathology and physiology of growth. For example Warren Lewis (7) long ago called attention to nucleolar enlargements of malignant fibroblasts of the rat. Kopac (8) has recently reported nucleolar extrusions in several types of human ovarian cancers in tissue culture. These were in tissues furnished by Dr. Long and described earlier from sectioned material (9), where hyperactivity (increased size) was correlated with degree of malignancy. Attention is directed to the interesting summary of Bang (10) on the electron microscopy of nuclear and cytoplasmic changes resulting from virus infections. From the same standpoint of electronmicroscopy Fawcett (11), using thin sections of this frog kidney tumor, has recently reported intranuclear inclusion bodies arranged in rows of hollow spheres "suggesting crystalline order," thus confirming our earlier light-microscope observations. In addition his electronmicrographs showed sheaves of dense filaments and aggregations of vacuoles, both of unknown origin in the cytoplasm. Intranuclear vaccinia virus particles, as well as those of molluscum contagiosum within the nucleolus, have been described in detail by Melnick *et al* (12).

From the foregoing it is evident that the work of various investigators, from many different viewpoints, is converging on the cell nucleus. In the frog kidney we have shown that the differences between benign and malignant neoplastic growths are due primarily to nucleolar hyperfunction, not so much of kind as of degree (3, 13). It is thought that other laboratories can now test these hypotheses in higher animals, employing tissue cultures in conjunction with tumor-filtrates. In particular it would be interesting to explore the question as to whether organ-specific viruses are less rare than commonly supposed. Of exceptional value would be the finding that such growth-promoting substances can be of endogenous origin as well.

REFERENCES

(1) "Viruses as Causative Agents in Cancer," *Ann. N. Y. Acad. Sci.*, **54**, Art. 6 (1952).
(2) B. LUCKÉ, *J. Exptl. Med.*, **68**, 457 (1938).
(3) W. R. DURYEE, *Ann. N. Y. Acad. Sci.*, **63**, (1956). (In press).
(4) T. CASPERSSON, "Cell Growth and Cell Function," New York, Norton, 1950.
(5) D. MAZIA, "Physiology of the cell nucleus" in "Modern Trends in Physiology and Biochemistry," New York, Academic Press, 1952.
(6) V. BUSH, W. R. DURYEE AND J. A. HASTINGS, *Rev. Sci. Instr.*, **24**, 487 (1953).
(7) W. H. LEWIS, *Cancer Research*, **3**, 531 (1943).
(8) M. J. KOPAC, (Personal communication).
(9) M. E. LONG AND H. C. TAYLOR, JR., *Ann. N. Y. Acad. Sci.*, **63**, (1956). (In press).
(10) F. B. BANG, *Fed. Proc.*, **14**, 619 (1955).
(11) D. W. FAWCETT, *Anat. Record*, **122**, 488 (1955).
(12) J. L. MELNICK, H. BUNTING, W. G. BANFIELD, M. J. STRAUSS AND W. H. GAYLORD, *Ann. N. Y. Acad. Sci.*, **54**, 1214 (1952).
(13) W. R. DURYEE AND J. K. DOHERTY, *Ann. N. Y. Acad. Sci.*, **58**, 1210 (1954).

BOOK REVIEWS

HYDROGEN PEROXIDE, by Walter C. Schumb, Charles N. Satterfield and Ralph L. Wentworth. ACS Monograph No. 128. 759 pages, tables, graphs and line drawings, 16 × 24 cm. New York, Reinhold Publishing Corp., 1955. Price, $16.50.

This is a valuable addition to the library of inorganic chemistry. It is "the first complete treatment of the manufacture, properties, technology and uses of hydrogen peroxide in English." The authors have been active in research on hydrogen peroxide during the past decade and so have been in a position to write to a considerable extent on the basis of knowledge gleaned from personal experimentation.

The importance of hydrogen peroxide as an item of commerce may be realized from the fact that the production for the current year will be in the neighborhood of 50,000,000 lbs. (25,000 tons). For many years the substance, as a three per cent solution, has occupied a place on our home medicine shelves and has found use as a disinfectant but this not-inconsiderable production indicates its importance also in industrial chemistry.

The book gives a highly satisfactory treatment and, as attested by the more than 2500 references given, represents a thorough study of the subject. It is well arranged and systematically presented. In the main, the authors have confined themselves to the inorganic and physical features of hydrogen peroxide and certain related substances. Because of lack of space, they felt compelled to avoid the inclusion of organic derivatives "except incidentally."

The scope of the treatment may best be indicated by a partial listing of chapter contents:

The first three chapters summarize methods of formation and manufacture. This section of about 150 pages concludes with 20 pages devoted to the modern electrochemical methods of manufacture by which the substance is now made commercially. Chapter 4 deals with the concentration and purification of the crude product and with precautions in handling. The well known tendency of concentrated peroxide to explode or to decompose in the presence of catalysts makes this discussion desirable. Chapters 5, 6 and 7 discuss the physical and chemical properties of hydrogen peroxide including thermodynamic relations and mechanism of reactions. The following two chapters discuss the decomposition process and factors of stabilization. One chapter is given to analysis of hydrogen peroxide solutions and testing for the presence of the substance in various materials. Another discusses various inorganic derivatives, mostly peroxides.

The uses of hydrogen peroxide are brought together in one chapter of about 65 pages. Among the applications discussed are: Bleaching, utilizing about 70 per cent of the entire product; bleaching of cellulose materials, wood pulp and wool; oxidation of dyestuffs, as in some processes of vat dyeing; photographic processes; cleaning of metal surface; as a propellant for rockets and submarines, in which cases the hydrogen supplies the energy by its decomposition; as a bactericide and disinfectant.

Numerous tables and graphs add interest and lucidity to the book. It is excellently printed and bound, as have been the other members of this important A. C. S. Monograph series. WILLIAM B. MELDRUM

COLOR TELEVISION STANDARDS, edited by Donald G. Fink. 520 pages, drawings, photographs and color plates, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $8.50.

Mr. Fink is well known as the great explainer of commercial electronics. His writings for many years as editor of "Electronics," and later in connection with radar and television, attest his proficiency in this role. In his new book Mr. Fink again edits and presents in ordered form the contents of the

final report of the National Television System Committee. This has been done with great care and with much attention to the details of reference. Extensive references are necessary here since there is much that is important in the history of the Committee's work and since so many persons deserve credit for the various undertakings. The organization of the chapters of the book follows closely the panel assignments of the NTSC.

It is extremely gratifying to see the contents of the eighteen huge volumes of the NTSC report condensed into a single book of convenient proportions. In compressing a volume of the NTSC report into a single chapter or less, it might seem that much of the original material would have been omitted. However, the reviewer has had occasion to examine the volumes of the NTSC report and feels that they are excessively documented with copies of correspondence and similar material which would not be of general interest. The NTSC report does stand as an excellent record for the lawyers and those who will be involved in matters, but Mr. Fink has extracted most of the valuable technical disclosures which are of importance to the engineer. Mr. Fink has also included some non-technical details (among them, the number of receivers supplied, and the names of the companies supplying them) in his dramatically descriptive Field Tests section.

Of greatest value are those portions of the book which explain and demonstrate the reasons for the phenomena which underly and govern the operation of the color systems. Some of the demonstrations are highly mathematical and are carried out with engineering excellence by whoever originated the work. For instance, the early portion of the book contains a vast amount of excellent material on the subjective aspects of color and color principles in general. In addition to finding answers to specific television problems, one therefore gains in knowledge of color concepts; and this knowledge will undoubtedly be sought by others not necessarily concerned with television application. Moreover, it should be appreciated that these writings represent the combined effort of a large number of this country's best authorities in the various fields. Of particular note is F. J. Bingley's contribution to the colorimetry of color television; and there are many others.

In summary we may conclude that a useful service has been rendered by extending to the technical press the contents of the NTSC proceedings whose distribution was necessarily limited to Committee members, government agencies, and technical libraries. The details of the NTSC's great undertaking may also be said to represent a master blueprint for large-scale coordination and evaluation projects which may be initiated in other fields. C. W. HARGENS

DIFFUSION AND HEAT EXCHANGE IN CHEMICAL KINETICS, by D. A. Frank-Kamenetskii, translated from the Russian by N. Thon. 370 pages, diagrams, 15 × 23 cm. Princeton, Princeton University Press, 1955. Price, $6.00 (paper).

Diffusion and Heat Exchange in Chemical Kinetics is a translation of a 1947 Russian book, the subject matter of which is well described by the title. Certainly there has been a need for a book on this rather recently developed approach to kinetics which is, in many aspects, quite controversial. It is unfortunate that this book is admittedly limited to the opinion and work of one group. The references as well, are overwhelmingly Russian. Most of those interested in the book are probably well acquainted with the work of Frank-Kamenetskii.

A few comments are pertinent to the general style and organization of the book. The presentation is somewhat terse and concise; the language is the somewhat stilted style typical of a translation. The subject matter is presented systematically and a good background is presented for each topic. Although a certain acquaintance with the subject is assumed, a brief treatment is given some elementary introductory topics. There is, however, some confusion in the organization. There are errors in the style of type and the position of headings and subheadings within the chapters, making it difficult to understand the organization. The body of the book disagrees with the table of contents in this respect. The organization is aided by a good introduction to each chap-

ter. A helpful list of symbols adds to an otherwise short and incomplete index.

As previously mentioned, the book is limited mainly to the opinions of Frank-Kamenetskii. The controversial aspects of the field are thus not well covered but are presented in a biased manner. In certain cases where data were given to show agreement with his equations, it appears the data were carefully chosen to do so.

The opinion must not be taken that the reviewer finds the book too full of warped viewpoint and poor style to be worthwhile. It is important, if for no other reason than the lack of any other book on the subject; and its systematic coverage of the subject is to be commended. Perhaps a glance at the Foreword and the Preface would be beneficial to the potential reader.

M. H. BORTNER

LIQUID-LIQUID EXTRACTION, by L. Alders. 206 pages, diagrams, 16 × 24 cm. Houston, Elsevier Press, 1955. Price, $5.50.

Extraction is a physical method of separation in which one or more constituents are removed from a mixture by the addition of a liquid which exerts preferential solvency for the constituents to be removed. Most books that deal with this subject approach it from the theoretical (physical-chemical and thermo-dynamics) aspect; and since extraction is currently gaining more widespread industrial usage, there exists a need for a source book that treats the subject more practically. The author has tried to answer this need with his book.

The book itself consists of six chapters. The first chapter presents a review of the phase rule and the second chapter deals with the theory and calculations involved in the equilibria of ternary systems. The remaining chapters give comprehensive coverage to the four principle methods of liquid-liquid extraction: namely, cross-current extraction, countercurrent extraction, two solvent extraction, and extraction with reflux. Each extraction procedure is discussed from the standpoint of the data required to make extraction calculations, the actual calculations, theoretical concepts involved, and finally suggestions for small scale plant operations using the particular extraction method.

The author's avowed purpose for writing this book was "to provide systematic and detailed knowledge of the theory of liquid-liquid extraction and its application in industrial laboratories." However, in the opinion of the reviewer, the accent was placed on presenting the details rather than the knowledge. Much of the detail information, both theoretical and experimental, was unnecessarily labored and could have been greatly condensed and in some cases eliminated entirely. Owing to the myriad of examples used, reading was difficult and confusing, but if summaries had been included at the end of each chapter much of this confusion could have been eliminated. Even though the book has some bad points it does provide both a comprehensive source of up-to-date information on the field and many helpful suggestions to workers who use extraction. The book also helps to fill a real need in the field and hence it must be recommended to those scientists who must use liquid-liquid extraction in their activities.

DONALD H. RUSSELL

BEARING LUBRICATION ANALYSIS, by R. R. Slaymaker. 108 pages, illustrations, diagrams, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $5.00.

Over the past fifteen years the general term Bearing Lubrication Analysis has come to denote a subject that includes many general types of bearings operating over a wide range of bearing environments. The journal bearing can be straight sleeve, tilting pad or hydrostatic and the thrust bearing can be parallel faced, tilting pad or hydrostatic. Of the environments, high speed, dynamic loading, and severe load and temperature requirements are common in our present day machines. As the author points out in the preface "This book deals with sleeve bearings, the most common type of bearing found in machines." The title of this book is therefore quite misleading.

In treating the sleeve bearing the author has, in a logical manner, introduced the reader to various phases of analyses that lead to the final solution. After a brief introduction to the subject, a chapter is devoted to the properties of oil, its viscosity, its definition, how it is affected by tempera-

ture, etc. and analysis and application for its measurement. The next two chapters are devoted to sleeve bearing analysis. The summation of forces on a differential particle of fluid in the bearing clearance annulus is first described. Using Newton's law of viscous flow and the continuity criterion the Reynolds differential equating is obtained. The analysis is based on one dimensional flow and the resultant equation is therefore not in the complete form to include, theoretically, end flow in the bearing. The equations for pressure distribution, load-carrying capacity and friction torque are derived considering no end flow. End flow is, however, taken into account using empirical constants that are tabulated as a function of journal eccentricity and bearing width to diameter ratio.

Particular attention is given to oil flow and temperature rise in the bearing. Equating the heat generated by the shaft and the heat removed by the oil the author substitutes this resultant equation in a modified equation for "flow through a slot." The temperature characteristics for a pressure fed sleeve bearing can then be obtained.

The remaining portion of the book is devoted to such practical considerations as physical design, recommended clearances, grooving and material selection. A chapter is devoted to boundary conditions, including an excellent discussion on "oilless bearings."

The text is well supplemented with large and clear curves that can be easily used to extract constants for use in the general equations. Also the clear sketches and photographs help to make the subject matter more easily understood. Although emphasis was placed on the temperature aspects of sleeve bearing analysis, it should be noted that high temperature lubrication, although not desirable, is becoming more common where greater demands are placed on our modern day machines. Therefore complete bearing analysis, with weight given to all factors, is essential.

STANLEY ABRAMOVITZ

CURRENT TOPICS

FRANKLIN INSTITUTE UNIVAC

The Franklin Institute and the Remington Rand UNIVAC Division of the Sperry Rand Corporation have jointly announced the signing of a contract for the installation of a complete UNIVAC Computing Center and an integrated Computation exhibit in The Franklin Institute in Philadelphia.

According to final plans, the center will be the largest of its kind in the world for public use and the first to be installed in a private institution. The Computing Center will be operated by Institute personnel under the supervision of Mr. Donald Houghton, Section Chief of the Analysis Section, Division of Electrical Engineering, The Franklin Institute Laboratories. The computations performed will be either for the Laboratories or for the public.

The computations for the Laboratories will relate to scientific or engineering problems which will be programmed by the Laboratories on behalf of various sponsors. Remington Rand computations usually relate to commercial and statistical problems to be programmed by them. Many of the Remington Rand and Franklin Institute computations will relate to the development of improved computing procedures.

Portraying the historical evolution of the art of computation from the abacus to the modern electronic computer, the exhibit area will graphically and dynamically convey the fundamentals of electronic computation. A guide will explain the operation of these mechanical "brains" in such a way that the complexities of these ultra-modern devices will be easily understandable to students and the average adult.

Over 300,000 Museum visitors per year will actually see a working electronic computing system. The device receives information for processing and instructions as to the method of processing. This information is stored in a "memory" for use when required. Through a series of logical or arithmetical operations it automatically processes this information according to instructions. Finally, the high speed printer of the UNIVAC prints the results at the rate of 78,000 characters per minute.

UNIVAC's great value lies in the tremendous speed with which it acts, the enormous amounts of information it can digest and its accuracy of results through its automatic self-checking features.

Other installations of UNIVAC large scale computing systems are Bureau of Census, Office of Air Comptroller, Army Map Service, Atomic Energy Commission, Bureau of Ships, General Electric Company (Louisville), Metropolitan Life Insurance Company, Wright Patterson Air Force Base, United States Steel Corporation, Franklin Life Insurance Company, Pacific Mutual Life Insurance Company, Chesapeake and Ohio Railway Company, Sylvania Electric Products, Inc., Consolidated Vultee Aircraft Corporation, National Advisory Council for Aeronautics, White Sands Proving Grounds, Air Force Armament Center, Operations Research Office, Westinghouse Electric Corporation and others.

The Franklin Institute installation

will be the first of its kind where a trained staff will be available immediately.

"The Franklin Institute has long been active in the field of computation. In recent years our work on general purpose digital machines has increased to the point that it became obvious that we could no longer afford to be without our own large scale computer. It is with great pleasure that we announce the availability of this modern UNIVAC system at The Franklin Institute," said Mr. S. Wyman Rolph, President of The Franklin Institute when making the announcement.

Low-Cost Micro-Projector for Science Classes.—Teaching microscope use and the study of microscopic specimens can now be done at low cost with the aid of a new micro-projector. Developed by the Bausch & Lomb Optical Co., Rochester, N. Y., the Tri-Simplex Micro-Projector is designed for schools with low budgets. It will permit science instructors quickly to introduce groups of students to microscope specimens by screen projection. Microscopes can then be used for individual study.

Teacher or pupil can easily use the micro-projector in any of three different ways: (1) projecting microscope slides onto a wall screen; (2) projecting images of living micro-organisms in liquid onto a wall screen; (3) projecting images for tabletop tracing.

The instrument will speed science instruction by permitting teachers to discuss microscopic specimens while they are being viewed simultaneously by all students.

Three microscope objectives can be mounted in a single objective carrier on the micro-projector, permitting rapid changes in the magnification of the specimen. A high power tube is also included for more detailed examination of slides.

An unusual feature of the Tri-Simplex Projector is its ability to project live specimens in liquid. Used in the horizontal position for this function, a mirror then directs the image to the wall screen. Specimens are protected from heat of the 100 watt lamp by an efficient heat absorbing glass.

B&L provides the science teacher with complete instructions for effective slide presentations, in addition to an operating manual. The 16-lb instrument is made to disassemble easily for storage purposes. Price of the Tri-Simplex Micro-Projector with one microscope objective is $150. Additional objectives are priced at $12 each.

The Tri-Simplex was shown for the first time at this year's annual meeting of the American Association of School Administrators of N.E.A. at Atlantic City, N. J., in February.

New Way to Make Transistors.—A new and improved technique for making transistors and other "solid state" devices from germanium has been developed by scientists at the Westinghouse Research Laboratories, it was announced by Dr. Clarence Zener, acting director of Westinghouse research.

The new technique already has been employed at the Westinghouse Research Laboratories to make two greatly improved types of transistors: (1) a transistor capable of efficient operation at extremely high frequencies such as those encountered in television and other high-frequency electronic devices, and (2) a special transistor, called a photodiode, which is 10,000 times more sensitive to light than a conventional photoelectric cell, or "electric eye," yet can control a hundred times more current.

"Many attempts have been made to develop transistors which will operate successfully at extremely high frequencies—far above those encountered in hearing aids and radios, where transistors are now finding general use," Dr. Zener said. "High-frequency applications, however, require better transistors, which means better ways of making them. We feel that our new technique is a major improvement over existing methods."

The new technique was originated by Dr. R. L. Longini, physicist at the Westinghouse Research Laboratories, who reported that it is an improved means of making junction-type, p-n-p germanium transistors.

He explained that conventional methods of making transistors rely on delicate temperature control to achieve quality and consistency in the finished product. "Ordinarily," he said, "a thin slice of n-type germanium is placed between two layers of the metal and heated. The metal atoms 'dissolve' inward through the germanium, forming two outside layers of p-type germanium and leaving a very thin n-type layer between them. The thinner and more uniform the n-layer, the better the performance of the finished transistor.

"Too high a temperature causes the very thin layer of n-type germanium to melt away completely, leaving the transistor worthless. Too low a temperature leaves the n-layer too thick, giving a transistor with poor performance."

In contrast, the new Westinghouse process can allow the temperature to be virtually uncontrolled—which means that, compared to conventional methods, the process inherently produces transistors more consistent in quality from unit to unit.

Key to the Westinghouse process is a "cooling off" period during the heating of the transistor. The process allows the critical n-layer to build up to the desired thickness and uniformity instead of being inexactly dissolved away, as in conventional methods.

While not yet applied to full-scale manufacture of transistors, Dr. Longini reported that the new process, on a laboratory scale, had produced transistors with unusual performance. Such transistors can amplify electrical pulsations many times higher in frequency than those handled by the usual junction-type transistor. This means that soon we may see high-frequency electronic equipment—including home television sets—fully transistorized, with the usual array of electronic tubes completely replaced by transistors.

Westinghouse's new technique has also produced transistors which are super-sensitive to light, Dr. Longini revealed. These transistors, called photodiodes, use the energy of light to control electric currents, just like an ordinary photoelectric cell or "electric eye." However, they are at least 10,000 times more sensitive to light, and one of them can control as much current as 100 typical photoelectric cells combined.

The Westinghouse scientist pointed out that the usual photoelectric cell requires vacuum tubes, transformers and other bulky circuit components to furnish power to the tube and amplify its small electrical output. The new photodiode needs none of this. It operates on a voltage as low as that from a 1½-volt dry cell or 6-volt storage battery yet can operate a standard relay without amplification.